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Quick Indicator Tests to Characterize Bentonite Type

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QUICK INDICATOR TESTS TO CHARACTERIZE BENTONITE TYPE

by

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16. ABSTRACT

Ten commercially available bentonite products representing unaltered, polymer protected, and chemically treated sodium bentonites were used in laboratory testing. The purpose was to identify a quick, reliable, cost-effective and field practical indicator test procedure which permits: identification of bentonite type; prediction of the hydraulic conductivity performance of the bentonite under chemical or leachate attack, both in pure form and when admixed with other soils for use as slurry trench backfill.

A total of eighteen test procedures were applied to the bentonites in slurry or powdered form for several bentonite concentrations, several acetone concentrations, and three general hydration cases. Results demonstrate that the gel strength and apparent viscosity tests may be used to distinguish between the specific unaltered, polymer protected or extended, and chemically treated bentonites tested.

A total of ninety-five hydraulic conductivity tests were performed on various soil-bentonites and bentonite filter cakes. Results indicate that the hydraulic conductivity of bentonite filter cakes permeated by a mixture of 25 percent acetone in water was not significantly different from baseline (0% acetone) results. Moreover, there was no performance distinction to be made on the basis of bentonite type.

Selected indicator parameters were measured on the same slurries used to prepare filter cakes for hydraulic conductivity testing. Results for the 10-minute gel strength test suggested an apparent qualitative correlation with hydraulic conductivity as a function of acetone concentration.

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FOREWORD

Today's rapidly developing and changing technologies and industrial products and practices frequently carry with them the increased generation of solid and hazardous wastes. These materials, if improperly dealt with, can threaten both public health and the environment. Abandoned waste sites and accidental releases of toxic and hazardous substances to the environment also have important environmental and public health implications. The Hazardous Waste Engineering Research Laboratory assists in providing an authoritative and defensible engineering basis for assessing and solving these problems. Its products support the policies, programs and regulations of the Environmental Protection Agency, the permitting and other responsibilities of State and local governments and the needs of both large and small businesses in handling their wastes responsibly and economically.

This report describes the results of comparative tests that were examined as aids in identifying bentonite products. These products are used in pollutant containment systems built of earthen materials. The data will be useful to earth science and engineering professionals involved in design, construction, and testing of earthen barrier structures.

For information, please contact the Waste Minimization, Destruction and Disposal Research Division of the Risk Reduction Engineering Laboratory.

Timothy Oppelt, Acting Director
Risk Reduction
Engineering Laboratory

ABSTRACT

Ten bentonite products comprising three general type categories were subjected to selected laboratory tests to identify: 1) an indicator test procedure for (quick) jobsite QA type-distinction purposes; 2) type-specific differences in hydraulic conductivity of the various products when permeated by varying concentrations of acetone, both in pure form and as amended to other clays (soil-bentonites); and 3) an indicator test procedure to permit (quick) prediction of chemical (acetone) impact on the hydraulic conductivity of bentonites in pure and amended form.

A total of eighteen test procedures were applied to the bentonites in slurry or powdered form for several bentonite concentrations, several acetone concentrations, and three general hydration cases: water only, "hydration" in the test acetone/water solution, and acetone exposure after full water hydration. Results of a one-way analysis of variance demonstrate that the gel strenth and apparent viscosity tests may be used to distinguish between the specific unaltered, polymer protected or extended, and chemically treated bentonites tested.

A combined total of ninety-five hydraulic conductivity tests were performed on various soil-bentonites and bentonite filter cakes. API filter press cells were converted for use as miniature rigid wall permeameters. Samples were permeated with the same concentrations of acetone used in indicator test work.

Results indicate that the hydraulic conductivity of bentonite filter cakes permeated by a mixture of 25 percent acetone in water was not significantly different from baseline (0% acetone) results. Moreover, there was no performance distinction to be made on the basis of bentonite type.

Comparable testing of soil-bentonites, however, demonstrated a pronounced effect due to bentonite content of the sample. For example, conductivity was reduced more than 1.3 orders of magnitude on the average by increasing bentonite content from one percent to five percent. About one order of magnitude reduction was attributed to the effects of acetone concentration and bentonite type. For two of the three bentonite concentrations tested, the polymer protected/extended bentonite had the least hydraulic conductivity for all permeants, followed by the chemically treated and unaltered bentonites.

Selected indicator parameters were measured on the same slurries used to prepare filter cakes for hydraulic conductivity testing. Results for the 10-minute gel strength test suggested an apparent qualitative correlation with hydraulic conductivity as a function of acetone concentration. A quantitative correlation was not attempted, however, since the test concentrations of acetone had insignificant effect on the hydraulic conductivity of bentonite filter cakes.

A qualitative correlation in the case of soil-bentonites of varying bentonite content was not observed for any permeant liquid used herein.

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SECTION 1

INTRODUCTION

The Land Pollution Control Division, Containment Branch, of the Hazardous Waste Engineering Research Laboratory, is conducting research to evaluate the effectiveness of earthern barriers to prevent the movement of contaminated groundwater from hazardous waste sites. Of particular interest are the immediate and long-term performance characterics of such barriers under the influence of organic contaminants and leachates. Various soil-bentonite mixtures are utilized as barriers in the form of slurry cutoff walls. The selection and specification of a particular bentonite for use in slurry wall construction is often an application-dependent decision involving cost and subjective performance considerations. Sodium bentonites are generally classfied by vendors as unaltered, polymer protected or extended, and chemically treated. Currently, there is no test protocol to distinguish between these bentonite type classifications or to evaluate relative in-service hydraulic conductivity performance under chemical or leachate attack.

The purpose of this research is to identify an indicator test procedure which can be characterized as quick, reliable, cost-effective and field-practical, and which permits:

- identification of bentonite type (type-distinction)
- prediction of the hydraulic conductivity performance of the bentonite under chemical or leachate attack, both in pure form and when admixed with other soils for use as slurry trench backfill (soil-bentonite).

A corollary objective of type-distinction is type-characterization. That is, if a test can be identified which permits identification of bentonite types, then it can be demonstrated that the various types are different, and the results of such a test would also serve to define those differences.

Variables affecting the equilibrium hydraulic conductivity of different bentonites as used in environmental applications are numerous and not fully understood. In addition to inherent natural variation at the source and between different source areas, the nature and extent of chemical modification during manufacture generally is not known to the engineer or scientist responsible for design and specification. Also, the range of candidate indicator test procedures and chemical permeants which could be evaluated is extreme. The scope of this study was therefore limited.

The research was performed in three consecutive phases from June 1, 1984 to September 30, 1986. A total of ten different vendor-supplied bentonite products were studied using eighteen test procedures, three different bentonite hydration procedures and eight test liquids; including deionized water, acetone in various concentrations, and 100% methanol and xylene. The project involved almost 2000 separate indicator test runs (including replicates) and a total of 95 hydraulic conductivity tests.

Phase I involved the application of ten indicator tests using two hydration procedures and three test liquids (deionized water, 25% acetone, 75% acetone) to determine the rationale for and scope of subsequent research. An interim technical report was issued in November 1984 under the title "Investigation of The interaction Between Bentonites and Soil Bentonites with Organic Chemicals".

Phase II research involved four additional test procedures, one additional bentonite hydration condition, three additional concentrations of acetone (5%, 15%, 50%), and 100% methanol and xylene. About 64% of all indicator test data reported herein were generated during Phase II in an effort to establish a statistically viable data base for evaluation. A second interim technical report was submitted in November 1985.

The focus of Phase III research was threefold: to further examine the most promising test procedures; to perform a statistical analysis to determine which tests, if any, could be used to distinguish between unaltered, polymer protected or extended, and chemically treated bentonites; and to determine the relationships, if any, between indicator test parameters and hydraulic conductivity.

Phase III testing involved nine test procedures, two of the three bentonite hydration procedures previously used, and selected test liquids (deionized water, 25%, 50%, and 75% acetone, and 100% methanol).

All work discribed herein was performed in accordance with an approved Quality Assurance Project Plan (March 27, 1985) and Safety Plan (July 1985) and subsequent addenda thereto.

SECTION 2

CONCLUSIONS

TYPE-CHARACTERIZATION

- Based upon the limited population sampling of bentonite products for this study, it cannot be said that unaltered, polymer protected/extended, or chemically treated bentonites constitute the only legitimate type-categories, or that these three types as defined herein are fully characterized.

- Of the ten vendor supplied bentonite products compared during the course of this study, those categorized as polymer protected or extended exhibited the widest range of response as a type-group and also were the most variable when compared to new lots of the same product (40 percent to 150 percent different, depending upon indicator test applied).

- The swell potential of the unaltered bentonites studied is strongly dependent upon the initial water content of the sample, whereas the swell potential of the polymer protected/extended and chemically treated bentonites apparently is independent of initial water content within the ranges tested herein.

- The swell potential of polymer protected/extended bentonites may be as much as twice as great as that of the unaltered and chemically treated types.

- Although the interpretation of results for the modified swell test was complicated by differences in the initial water content of bentonite samples, the test should be further evaluated in any future effort relative to bentonite type-characterization and type-distinction.

TYPE-DISTINCTION

- Within the scope of this study and considering all major sources of variability (operator effects, slurry batching effects, differences between different lots of the same bentonite product), it is possible to distinguish between unaltered, polymer protected/extended, and chemically treated bentonite types on the basis of results from selected indicator tests.

- When fully water-hydrated prior to exposure to acetone concentrations in the range of zero to 50%, the behavior of the bentonite types is not sufficiently different to permit type-distinction.

- Although several indicator test procedures permit limited type-distinction, those employing the rotational viscometer to measure various bentonite slurry parameters are the most useful for type-distinction purposes.

- Based upon a one-way analysis of variance of all results for selected tests, the 10-second gel strength test, the 10-minute gel strength test, and the apparent viscosity test may be used to distinguish between the three bentonite types using a chemically "hydrated" 25 percent acetone slurry having a bentonite concentration of 5 percent (weight: volume basis).

HYDRAULIC CONDUCTIVITY

- Initial bentonite concentration of a slurry has little, if any, measurable effect on the equilibrium hydraulic conductivity of filter cakes formed via slurry filtration, regardless of the acetone concentration of the permeant liquid (up to 50 percent) and bentonite type.

- Within the range of concentrations tested (25%, 50%), acetone has the effect of reducing the equilibrium hydraulic conductivity of filter cakes for all bentonite types, but generally by less than 0.1 order of magnitude relative to baseline results; an insignificant magnitude considering inherent measurement errors.

- The greatest reduction in hydraulic conductivity of filter cakes relative to baseline (0% acetone) results is at an acetone concentration of 25 percent, with little or no additional reduction with increasing acetone concentration up to 50 percent.

- The equilibrium hydraulic conductivity of a filter cake derived from a chemically treated bentonite under standard conditions (described herein) may be less than that for comparable filter cakes of the unaltered and polymer protected/extended types, but not by more than about 0.2 order of magnitude.

- For the range of acetone concentrations tested herein, bentonite concentration has a greater effect on the hydraulic conductivity of a bentonite-amended soil (soil-bentonite) than bentonite type.

- Increasing the bentonite content of a standard soil-bentonite from 1 percent to 5 percent (dry weight basis) decreases the hydraulic conductivity by about 1.3 orders of magnitude on the average.

- The maximum observed difference in hydraulic conductivity between different soil-bentonites due to bentonite type is about one order of magnitude (difference observed for polymer protected bentonite relative to unaltered bentonite at equivalent concentrations).

- For the acetone concentrations tested herein, in all cases but one the hydraulic conductivity of the soil-bentonite samples decreased, or changed very little, with increasing concentrations of acetone. Due to differences in testing methods and materials, however, results for tests using 75% acetone cannot be compared directly with data published by others.

INDICATOR/CONDUCTIVITY CORRELATION

- A quantitative correlation between indicator test parameters studied herein and the hydraulic conductivity of pure bentonites (filter cakes) and soil-bentonites permeated by varying concentrations of acetone cannot be demonstrated.
- A qualitative correlation between hydraulic conductivity and 10-minute gel strength was observed for filter cake samples representing each of the three bentonite types.
- This apparent correlation has no practical utility, however, since acetone was observed to have an insignificant effect on the hydraulic conductivity of bentonite filter cakes (about 0.1 order of magnitude or less).
- A similar qualitative correlation was not observed for soil-bentonites under any set of test conditions.

SECTION 3

RECOMMENDATIONS

Based upon the foregoing conclusions and the stated scope and objectives of this research effort, the following general recommendations are tendered:

- Although a type-distinction capability can be demonstrated for the specific unaltered, polymer protected/extended, and chemically treated bentonites tested herein, utilization of such for Quality Assurance or any other purpose should not be initiated until substantial verification testing is completed on a much wider sampling of the population of commercial bentonite products.

- Both in terms of initial (baseline) and long-term (multiple pore volume displacement) hydraulic conductivity after acetone exposure, it appears to matter very little which of the three bentonite types is used in the case of filter cake systems. Based upon the data presented herein, however, such cannot be said for soil-bentonites and probably not for other bentoniteamended clay barriers such as compacted liners (hydraulic conductivity under permeation by acetone differs by nearly an order of magnitude for samples amended by unaltered as compared to polymer protected bentonite). The question, "which bentonite type yields the best long-term bentonite-amended clay barrier for different contaminants" therefore remains unanswered. Any future research effort to resolve this question should focus on long-term chemical exposure of the barrier and should employ several priority pollutants as permeant liquids instead of an "artificial" chemical permeant which produces data of highly limited utility.

- Although a qualitative correlation between the 10-minute gel strength test and the hydraulic conductivity of filter cakes permeated by acetone can be demonstrated, such is not demonstrated in the case of soil-bentonites. It appears that there is no substitute for long-term multiple pore volume hydraulic conductivity testing and that the concept of a "quick indicator", especially in the case of bentonite-amended clays, may be tenuous.

SECTION 4

MATERIALS AND METHODS

BENTONITES

The ten sodium bentonite products used in the three phases of this study are listed in Table 1 along with an identification number used throughout the study and vendor-supplied information on typical environmental engineering applications. Specific information on the type and extent of chemical or physical modification during manufacture generally is not available.

The term "unaltered" as used herein indicates a naturally occurring sodium bentonite or a blend of different grades of naturally occurring sodium bentonite that has not been subjected to chemical or physical alteration or modification.

The term "polymer protected or extended" indicates a naturally occurring sodium bentonite that has been polymer "amended" either to enhance its resistance to chemical degradation or to improve its yield for economic reasons (also termed "peptised" indicating polymer enhancement such that less bentonite is required to achieve any number of specified minimum performance criteria). The type and degree of polymerization generally is application-dependent, which may result in substantial difference between two shipments of the "same" product.

The category termed "chemically treated" represents products that are designed to resist in situ degradation under chemical or leachate attack. The treatment is designed to prevent cation exchange, although the specific nature of the chemical treatment is proprietary.

CHEMICALS

Chemicals employed throughout this study were reagent-grade acetone, methanol, and xylene supplied by the U.S. EPA AWBERC stock room. Permeant liquids containing various concentrations of acetone were prepared for this study by directly mixing the acetone with deionized water in the appropriate proportions. Deionized water was also used in the mixing of all test slurries. A schematic and other details of the Center Hill deionized water system are presented in section 7.1 of the Quality Assurance Project Plan for this project.

TABLE 1. BENTONITE TYPES TESTED AND TYPICAL APPLICATIONS

BENTONITE TYPE	I.D. NO.	TYPICAL APPLICATIONS
Unaltered sodium bentonite	Bentonite No. 1 Bentonite No. 2 Bentonite No. 4	Fresh water lagoons Domestic sewerage lagoons Fly ash lagoons Sanitary landfill caps Water control projects Non-hazardous chemical wastes
Polymer Protected or Extended sodium bentonite	Bentonite No. 3 Bentonite No. 7 Bentonite No. 8	Toxic waste landfill impoundments Chemical waste disposal sites Industrial waste lagoons Slurry trench cutoff walls
Physically Altered sodium bentonite	Bentonite No. 9	Toxic waste repositories with high levels of organic solvents, inorganic chemicals, waste leachates and petroleum soaps
Physically Altered Amine Treated sodium bentonite	Bentonite No. 10	
Chemically Treated sodium bentonite	Bentonite No. 5 Bentonite No. 6	Contaminant resistant; used for containing wastes with high levels of dissolved salts, acids or alkalies

TESTS

Indicator Tests

The majority of indicator tests used in the course of this study involved the testing of a bentonite/water slurry or a bentonite/water/chemical slurry and may be termed "slurry characterization" tests. These tests are generally employed in bentonite manufacture and by consumers of bentonite products (petroleum exploration for example) to monitor key slurry properties such as viscosity and gel strength. The scope of testing also included several tests that are generally associated with either geotechnical engineering or environmental science. In addition, a few new test procedures were developed in-house or adopted from other consultants and researchers evaluating special bentonite testing methods.

Table 2 lists the indicator tests, their type (slurry characterization, geotechnical, etc.), procedural reference, and use in this study by research phase. As a key to the reference sources in Table 2, the general sources of documented procedures are:

1 - American Petroleum Institute (API)
Technical Bulletin API RP 13B
10th Edition

2 - Engineering Properties of Soils and Their Measurement
2nd Edition, Joseph E. Bowles, 1978

3 - U.S. Army Corps of Engineers Laboratory Soils Testing Manual
Document EM 1110-1-1906, 1970

4 - Standard Methods for the Examination of Water and Wastewater
14th Edition, APHA-AWWA-WPCF, 1975

5 - The United States Pharmacopoeia
20th Revision, National Formulary

6 - Annual Book of ASTM Standards
Vol. 04.08, 1984

Table 2 also indicates reference to a detailed step-by-step standard laboratory procedure (SLP) developed in-house for each of the tests. These SLP's are presented in Appendix D.

The listing of tests by phase in Table 2 reflects the refinement of the testing program to emphasize the most useful or promising tests for bentonite type-distinction. Several of these tests (Nos. 2-6) involved the use of an NL Baroid model 286 rotational viscometer used for QA monitoring of key slurry properties in petroleum exploration. Slurry is contained in an annular space between a rotating cylinder and a stationary bob as shown in Figure 1. The outer cylinder (rotor sleeve) is designed to rotate at pre-set constant velocity and transfer torque to the inner stationary bob via the viscosity of the slurry medium. A torsion spring restrains the movement of the bob. the angular displacement of the bob is read on a small optical scale at the top of the unit. Instrument constants are adjusted during manufacture so that various paramenters are determined at specific rotor sleeve speeds (see SLPs, Appendix D). An attempt was made to automate the rotational viscometer (and thereby limit the subjectivity of measurement inherent in the reading of the dial indicator) using and optical shaft encoder and a digital readout. The effort was unsuccessful, however, due to excessive shaft friction in the encoder itself and mechanical mounting tolerances which could not be achieved.

Sample Preparation

The particular procedure used to prepare samples for testing depended primarily upon the type of test and whether or not the bentonite was to be tested in slurry form. Tests such as free swell and liquid limit were performed on powdered bentonite samples as supplied from the vendor. Other tests, such as the modified swell test, involved chemical modification of

TABLE 2. SUMMARY OF INDICATOR TESTS STUDIED

Indicator Test	Type	Ref.	SLP No.	Research Phase I	II	III
1. Marsh Funnel Viscosity	SC	1	I-02	x	x	x
2. 10 second Gel Strength	SC	1	I-03	x	x	x
3. 10-minute Gel Strength	SC	1	I-03		x	x
4. Apparent Viscosity	SC	1	I-03	x	x	x
5. Yield Point	SC	1	I-03	x	x	x
6. Plastic Viscosity	SC	1	I-03	x	x	x
7. API Filtrate Loss	SC	1	I-04	x	x	x
8. Unit Filtrate Loss	SC-I	1	I-04	x	x	x
9. Modified Swell*	I	-	EX-02		x	x
10. Free Swell (2-hr.)*	E-I	-	G-04		x	
11. Free Swell (24-hr.)*	E	5	G-04	x	x	
12. Mud Weight	SC	-	I-01		x	
13. Specific Conductance	SC	1	E-03		x	
14. pH	E	4,1	E-01	x	x	
15. % retained, #200 Sieve	G	2,3,6	G-03	x		
16. Turbidity	E	4		x		
17. Cracking Pattern	I	-		x		
18. Liquid Limit*	G	2,3,6		x		
Total indicator tests by phase:				465	1209	316
Hydraulic conductivity tests by phase:				(27)	(27)	68

*Samples tested in powder or paste form

Type Key:	SC	Slurry characterization
	G	Geotechnical
	E	Environmental
	I	In-house or adapted

bentonite prior to testing in powdered form. Specific sample preparation procedures for these tests are reported in the form of SLP's in Appendix D.

Two specific SLP's were developed for the preparation (batching) of bentonite slurry, the primary distinction being whether or not the slurry was prepared from powdered bentonite or from a water hydrated bentonite paste (SLP Nos. S-01 and S-02, respectively).

The procedure involving powdered bentonite was used to prepare both standard "baseline" (0% chemical) slurries and chemically "hydrated" slurries wherein the bentonite was "hydrated" directly in the water or water/chemical solution. Data for baseline slurries generally reflect the normal level of response of the parameter of interest in typical slurry applications. Data for the chemically "hydrated" case were not intended to reflect a normal

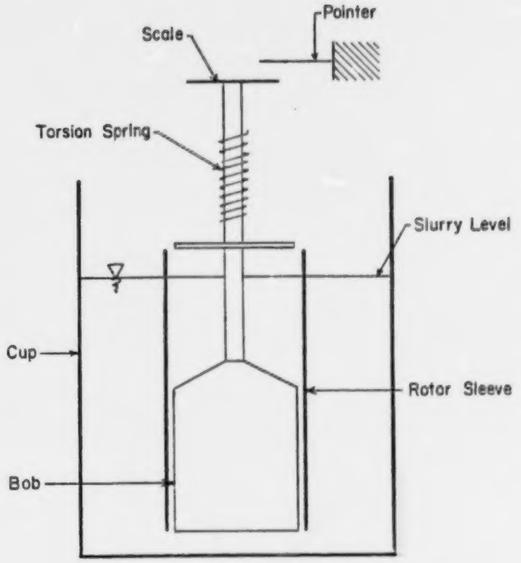


Figure 1. Schematic of rotational viscometer

slurry application, but rather, served to represent a different hydration case purely for type-distinction purposes (although chemical "hydration" may have limited relevance in connection with slurry mixing using contaminated site groundwater).

The procedure involving a water hydrated bentonite paste was employed both to provide a third slurry test case for type-distinction/characterization purposes and to reflect the more typical situation of chemical impact after full water hydration of the bentonite. This procedure (SLP No. S-02) involved the preparation of a standard paste for each bentonite (20% bentonite by weight), which was allowed to hydrate for several days. This paste was then mixed in the design proportion with the various water/acetone solutions to achieve the desired final slurry for testing. Table 3 lists the slurry hydration cases studied in each phase of the project.

All slurries were cured in airtight containers in a high humidity environment for a period of 24 hours prior to testing. This curing time was maintained in order to standardize bentonite hydration time and achieve a nearly full bentonite hydration state, although the actual degree of hydration was not known. Also, chemical interaction producing volume change affected the preparation of all water/acetone mixtures. For example, it was not possible to prepare 1000 ml of 25% acetone by direct admixing of 750 ml deionized water and 250 ml acetone. In all cases, the desired volume for testing purposes was decanted from a larger batch after chemically induced volume change had occurred.

TABLE 3. SLURRY HYDRATION CASES BY PHASE

Phase	Baseline (Water hydrated, 0% Acetone)	Chemically "Hydrated"	Water Hydrated, Chemically Modified
I	x	x	
II	x	x	x
III	x		x

Hydraulic Conductivity Tests

A total of 95 hydraulic conductivity tests were performed during the three phases of this study (Table 2). Initial work involved limited testing to develop optimized equipment to expedite hydraulic conductivity testing. Phases I and II employed API filter press cells as miniature rigid wall permeameters, and conventional rigid wall (compaction mold) permeameters.

Hydraulic conductivity testing in Phase III was standardized by employing only API cell permeameters to investigate the effect of acetone in various concentrations and to establish relationships between the various indicator test parameters and the equilibrium hydraulic conductivity of bentonite filter cakes and bentonite-amended clays. Schematics of the permeaters as used to test soil-bentonite and bentonite filter cake samples are presented in Figure 2.

Recent research by Barvenik, et.al.(1985) decribes the use of API cells for "quick" laboratory and field determination of hydraulic conductivity. The researchers tested three samples from each of five homogenized soil-bentonite batches and observed that results for two-thirds of the samples in each batch agreed within ± 10 percent of one standard deviation of the mean, with a worst-case precision of ± 57 percent (which was thought to reflect some nonhomogenity between samples despite thorough mixing). API cell tests were also compared with the more sophisticated triaxial procedure and observed to demonstrate a worst-case accuracy of ± 66 percent (total of 10 comparisons; triaxial results assumed to be "true" values). Results of this direct comparison are plotted in Figure 3.

Specific procedures for Phase III testing of bentonite filter cakes and soil-bentonite mixtures in API cells are presented in Appendix D as SLP's EX-03 and EX-04, respectively.

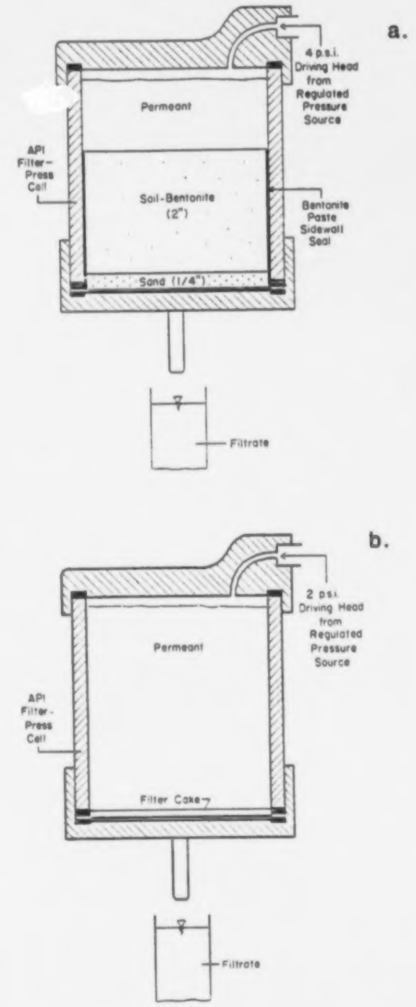

a.
4 p.s.i. Driving Head from Regulated Pressure Source
Permeant
API Filter-Press Cell
Soil-Bentonite (2")
Bentonite Paste Sidewall Seal
Sand (1/4")
Filtrate
b.
2 p.s.i. Driving Head from Regulated Pressure Source
Permeant
API Filter-Press Cell
Filter Cake
Filtrate

Figure 2: Schematic of API filter press cell as used for hydraulic conductivity testing of (a) soil-bentonites, and (b) bentonite filter cakes

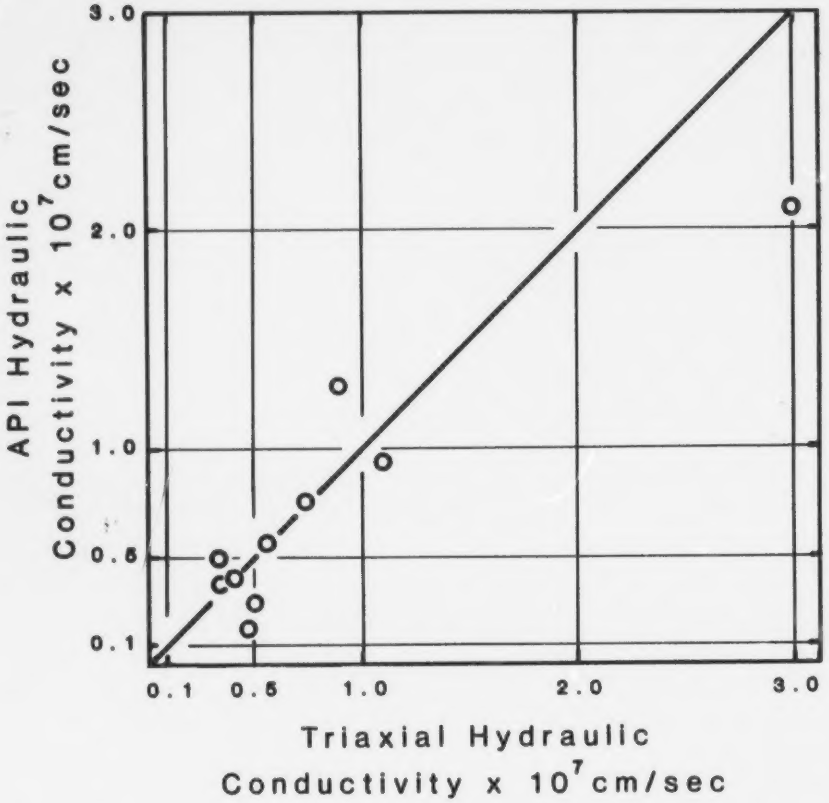


Figure 3. Comparison of API vs. Triaxial hydraulic conductivity (after Barvenik, et al., 1985).

SECTION 5

RESULTS AND DISCUSSION

GENERAL

The scope of the three research phases were intentionally different. To repeat, the testing strategy for Phases I, II, and III was to perform a preliminary evaluation of candidate tests, generate a large database using the most promising tests, and then refine the data set (fill in data gaps) as necessary to validate or disprove observed trends.

During the course of this project, however, several secondary issues were addressed which had bearing upon the primary objective of identifying indicator tests for bentonite type-distinction and hydraulic conductivity characterization. For example, in order to achieve a reliable type-distinction capability it was necessary to evaluate the sources of variability both for the test procedures used, and for the bentonite products themselves. Issues such as procedural and product variability are included in the following list of primary questions addressed during the course of this study:

- What is the expected magnitude of normal operator error in the performance of various tests and does it mask significant differences between bentonite types?
- What is the expected magnitude of normal error in the preparation of various batches of slurry for testing and is it significant relative to the experimental objectives?
- How uniform are different lots of the various bentonite products tested as indicated by the results of selected indicator tests?
- All sources of variability considered, which test or tests, if any, may be used as an indicator of bentonite type as defined herein?
- To what extent does acetone as permeant affect the hydraulic conductivity of a bentonite "filter cake" formed by filtration during slurry penetration into porous media?
- To what extent does acetone as permeant affect the hydraulic conductivity of a typical soil-bentonite mixture?

- How does acetone in varying concentrations affect the hydraulic conductivity of filter cakes and soil-bentonites of different bentonite concentration?

- What are the relationships between the indicator test parameters studied and the hydraulic conductivity of various bentonite filter cakes and a typical soil-bentonite permeated by varying concentrations of acetone?, i.e., which of the indicator tests, if any, is most useful as a predictor of chemical (acetone) impact for each of the bentonite types as defined herein?

These questions are not addressed for all possible experimental combinations (bentonite type, slurry concentration, hydration procedure indicator test, acetone concentration, etc.) since the scope of work over the three phases of this study was intentionally narrowed to focus on the most promising combinations of variables.

Due to the size of the body of data generated during this study, most tabular and plotted results are appended. Also, appended data are of several different classifications generated for various purposes. The various data sets are categorized and appended as follows:

A. Primary Tests: indicator tests performed and replicated to evaluate bentonite type-distinction potential, the utility of acetone in various concentations for type-distinction, and the significance of operator and slurry batching variability.

B. Secondary Tests: selected indicator tests performed with limited replication on new lots of three specific bentonites to generate data on the variability of typical bentonite products.

C. Correlation Tests: selected indicator tests performed with limited replication on selected bentonites both to augment the Primary data set for statistical evaluation, and to generate a new and distinct data set for direct correlation with results of hydraulic conductivity tests.

D. Permeability Tests: conventional and API cell hydraulic conductivity tests on selected bentonites and soilbentonites to determine the effects of various concentrations of acetone, and to determine the relationships to correlation test data.

Data for each of the above four categories appear in tabular and/or plotted form in Appendices A through C. Appendix A also contains several tables of statistical parameters for selected Phase II data sets.

SOURCES OF ERROR

Testing Method

Major sources of testing variability, and therefore potential experimental error, during the course of this study were:

- normal operator error during the performance of the various indicator tests.
- variations in technique between different operators for the same test(s).
- slight variations in sample preparation technique resulting in differences between batches of the "same" slurry.

Each of these sources was addressed in the quality Assurance Project Plan described in Section 6 of this report. For most of the testing (Phase II work) it was possible to eliminate the effects of variations in technique between different operators by assigning specific tests to specific operators. For a lesser portion of the testing (Phase III work) a single operator was assigned to perform all tests.

Quality assurance provisions in the form of standard laboratory procedures (SLP's, Appendix D) were implemented as an additional measure to minimize the impact of the three sources of error listed above.

In order to evaluate the sources of variability and determine their impact on the objective of bentonite type-distinction, a statistical analysis was performed on results from eight of the fourteen primary indicator tests performed during Phase II. An example reporting the mean (x), relative range (RR), standard deviation (σ), and coefficient of variation (CV) of marsh funnel viscosity test results for specific bentonites from each type-group is shown on the first page of Table 4. Similar data for this and the other ten indicator tests examined are presented in appended tables A-25 through A-35.

The statistical data base is limited in all cases to baseline (0% acetone) results, and results for the 25% acetone slurry in both the chemically "hydrated" and water hydrated slurry cases. The analysis was limited to these three cases since they comprise all test replication work for QA/QC purposes. Test replication typically involved an immediate replication of the test on the same batch of slurry, followed by a replication of the test on a new batch of the "same" slurry. In this way, variation due to sample preparation (slurry batching) technique was included.

The data also serve to estimate the variability due to normal operator error in the performance of the test. Analyst proficiency data (**, shown in right-hand column) were generated on a scheduled basis using a standard reference slurry (baseline) of one unaltered bentonite. Since a standard slurry was used, "batching" error was eliminated.

TABLE 4. STATISTICAL PARAMETERS - MARSH FUNNEL VISCOSITY TEST

		PRIMARY TESTS WITH REPLICATION*						ANALYST** PROFICIENCY
Bentonite Id.		1	3	7	9	10	5	2
Type		A Unalt	B Poly Prot(or)	B Poly Ext	C Phys Alt	D Phys Alt-AT '	E Chem Trtd	Unalt
No. of Reps		3	(3) 2	3	3	(3) 2	3	4
BASELINE Slurry (0% Acetone)	$\bar{x}$	35.6	(94.0) 111.2	44.2	37.0	47.0	31.2	42.8
	RR	9.6	(55.7) 1.4	10.9	10.3	7.7	8.7	18.7
	σ	2.0	(29.8) 1.1	2.5	1.9	1.9	1.4	3.4
	CV	5.6	(31.7) 1.0	5.7	5.2	4.1	4.5	8.0
CHEMICALLY HYDRATED Slurry (25% Acetone)	x	67.6	94.3	107.7	52.0	(132.7) 118.4	34.9	--
	RR	9.2	18.9	22.3	3.7	(34.2) 4 2	16.9	
	σ	3.4	9.0	12.0	1.0	(24.9) 3 5	3.2	--
	CV	5.0	9.5	11.1	1.8	(18.8) 3.0	9.1	--
WATER HYDRATED CHEMICAL Slurry (25% Acetone)	$\bar{x}$	43.1	98.7	78.3	46.7	74.5	42.6	--
	RR	18.6	17.8	21.3	13.3	16.1	23.0	
	σ	4.0	8.8	9.4	3.2	6.1	5.7	--
	CV	9.3	8.9	12.0	6.8	8.1	13.3	--

(continued)

TABLE 4. (continued)

		ALL PRIMARY TEST RESULTS*** (NO REPLICATES)					
Bentonite Id.		1,2,4	3,7,8	9	10	5,6	ALL
Type		A Unalt	B Poly Prot or Ext	C Phys Alt	D Phys Alt-AT	E Chem Trtd	ALL
BASELINE Slurry (0% Acetone)	$\bar{x}$	37.8	90.5	[36.7]	[49.2]	32.9	53.6
	RR	35.6	72.5	--	--	7.0	150.6
	σ	6.4	37.7	--	--	--	31.5
	CV	16.9	41.7	--	--	--	58.8
CHEMICALLY HYDRATED Slurry (25% Acetone)	$\bar{x}$	52.0	124.1	[51.0]	[120.9]	36.3	77.3
	RR	56.5	73.3	--	--	27.3	
	σ	16.9	51.9	--	--	--	47.7
	CV	-- 32.5	-- 41.8	--	--	--	-- 61.7
WATER HYDRATED CHEMICAL Slurry (25% Acetone)	$\bar{x}$	43.2	74.7	[47.4]	[75.4]	97.3	67.1
	RR	17.8	58.9			105.6	
	σ	4.2	25.3	--	--	--	34.6
	CV	9.7	33.9	--	--	--	51.6

* Includes operator and batching variability

** Operator variability; may include type variability for unaltered bentonites

*** Includes operator, type, and batching variability

Values in parentheses ( ) include "outlier" results
Values in brackets [ ] represent single sample

Data on the first sheet of Table 4 therefore include both batching and normal operator sources of variability.

An attempt was made to separate "operator" and "batching" effects based upon relative coefficients of variation (CV) for unaltered bentonites. Analyst proficiency data (**) represent normal operator error only. Data for primary tests with replication (*) include both sources of variability. As indicated for the baseline case in Table 4, normal operator variability (**) can be greater than the combined effects of operator and batching (*) (CV data circled). This is because the data sets were generated for two different unaltered bentonites (Nos. 1 and 2) and some degree of "within-type" varibility was therefore involved. The magnitudes of operator and batching variability are relatively modest and strict separation of these two effects may not be necessary if "within-type" variability is sufficiently large.

The second page of Table 4 (and similar appended tables) reports the overall variability observed for the five bentonite types (***). The data is somewhat normalized in the sense that they do not include replicate results (since not all bentonites were replicated to the same degree during the testing program).

Comparison of the overall CV value for the three unaltered bentonites in the baseline slurry case (*** = 16.9) with comparable CV values on the first page of Table 4 (* = 5.6, ** = 8.0) indicates that the overall variability of results for the marsh funnel viscosity test exceeds either operator or batching variability and their combined effect.

Table 5 is a summary of test method variability for all unaltered bentonites and selected indicator tests. The CV data are summarized from appended tables A-25 through A-35. The data suggest that operator and batching variability relative to overall variability for unaltered bentonites was least in the plastic viscosity test. Presumably, a "best-test" could be identified for the other four bentonite types in a similar fashion, but the use of such information in a type-distinction test protocol might require the performance of numerous different tests using different slurry hydration cases; a situation which would be less than "ideal".

The second page of Table 4 (and similar appended tables) also reports the overall variability of all bentonites irrespective of type classification. Statistical parameters for all bentonites are reported in the "All" column.

The foregoing discussions should be considered in proper perspective. The data cannot be used to identify a single ideal indicator test for type-distinction since neither CV data nor RR data are available for all type-groups (two of the five bentonite type-groups comprise only one sample, one of the groups comprises only two samples). The statistical analysis does, however, permit the following interim conclusions:

- Where available, relative range data (RR) lend credibility to the general type-classifications as defined herein. The relative ranges generally are considerably different, and the relative range of

"All" data for any indicator test always exceeds the relative range of any single type group for the same indicator test.

- The combined effects of operator and batching variability are different for different test procedures, but typically represent less than half of the overall variability (six of the eight test procedures investigated) and therefore generally should not preclude the recognition of important differences between the different bentonite types.

TABLE 5: SUMMARY OF OPERATOR AND SLURRY BATCHING VARIABILITY FOR SELECTED INDICATOR TESTS ON UNALTERED BENTONITES

Indicator Test	CV (operator + batching) bentonite No. 1	CV (operator only) bentonite No. 2 (analyst proficiency)	CV (operator + batching + within-type) bentonite Nos. 1,2,4	Percent of overall variability due to operator, or operator + batching*
Marsh Funnel Viscosity	8.0	5.6	16.9	47.3
10-sec Gel Strength	0.0	33.3	75.5	44.1
10-min Gel Strength	0.0	38.0	38.2	99.5
Apparent Viscosity	1.3	4.6	42.9	10.7
Yield Point	5.1	11.4	75.0	15.2
Plastic Viscosity	0.0	1.6	30.4	5.3
API Filtrate Loss	3.8	2.2	20.8	18.3
Unit Filtrate Loss	26.0	10.2	33.1	78.5

* Whichever is greater

Bentonite Products

One of the primary objectives is to identify an indicator test procedure which will permit distinction of the bentonite types. A secondary consideration in terms of the practical utility of results is the variability of the bentonite products themselves, i.e., are the specific bentonites tested likely to be so variable, either naturally or by design during manufacture, so as to invalidate any type-distinction test protocol developed within the scope of this study? Clearly, the question cannot be answered with a high level of certainty since only ten of over forty commercially available bentonites were tested. In addition, the limits of potential variation at the source area and subsequent modification during manufacture are not known. Despite these factors, a limited "secondary" investigation into the uniformity of bentonite products as supplied from the vendor was initiated.

Second (new) lots of three of the ten bentonites were obtained for testing. The samples included one bentonite each from the unaltered, polymer protected/extended, and chemically treated type-groups. Three indicator tests were then applied to each of the three bentonites. The slurry hydration cases used and results for the unaltered bentonite are presented in Table 6 (tabulated data for the other two bentonite types presented in Appendix B for Secondary Tests). The degree of product uniformity was evidenced by the difference in response between the two lots of the various bentonites tested under identical conditions. The data in Table 6 for the marsh funnel viscosity and unit API filtrate loss tests are plotted for each hydration case in Figures 4 and 5.

Plotted results suggest that, in general, differences between the two lots of unaltered bentonite No. 1 (lot 1- acetone, vs., lot 2- acetone) were minor. The percent difference for each test case was computed and appears in Figure 6 along with comparable data for the other two bentonites.

Although results are different for each slurry hydration case, the data in Figure 6 indicate that the unaltered bentonite was the most uniform of the three types tested, and that the polymer protected/extended bentonite was the least uniform, with differences between the two lots ranging from 40 percent to 150 percent, depending upon the slurry hydration case.

To again put the information into perspective, the source and potential magnitude of the differences noted above are not known for the population of commercial bentonite products. Natural variation at the source area, unintentional or intentional difference related to manufacture, or some combination of both may be involved. As such, the data do not resolve the issue of product uniformity within the context of a type-distinction testing protocol for general use, and therefore suggest a third interim conclusion:

- The results of this study apply only to the specific test conditions studied and should not, at this time, be extrapolated to apply to bentonites and chemicals other than those tested herein.

TABLE 6. SECONDARY INDICATOR TEST RESULTS (phase II)

Type: UNALTERED			CHEMICALLY 'HYDRATED' Slurry			WATER HYDRATED Chemical Slurry		
Bentonite Id: 1			% CHEMICAL IN DEIONIZED WATER					
IND. TEST	LOT	CHEMICAL	0 (BASELINE Slurry)	25	RI	25	RI	50
MARSH FUNNEL VISCOSITY (sec)	1	Acetone	36.4	68.5	72.1	49.2	49.9	55.4
	2	Acetone	34.2	72.6	74.4	52.0	45.5	51.2
	2	Methanol	"	36.3	37.5	57.0	56.0	35.4
API UNIT FILTRATE LOSS (ml/mm)	1	Acetone	6.7	5.0	5.8	6.2	6.1	5.1
	2	Acetone	8.2	5.4	5.7	5.9	6.3	7.1
	2	Methanol	"	6.3	6.2	8.6	6.5	9.7
SPECIFIC CONDUCTANCE (mmhos)	1	Acetone	.885	.508	.498	.620	.536	.369
	2	Acetone	1.144	.794	.795	.719	.735	.368
	2	Methanol	"	.696	.699	.410	.411	.482

NOTE: Slurry not remixed prior to test

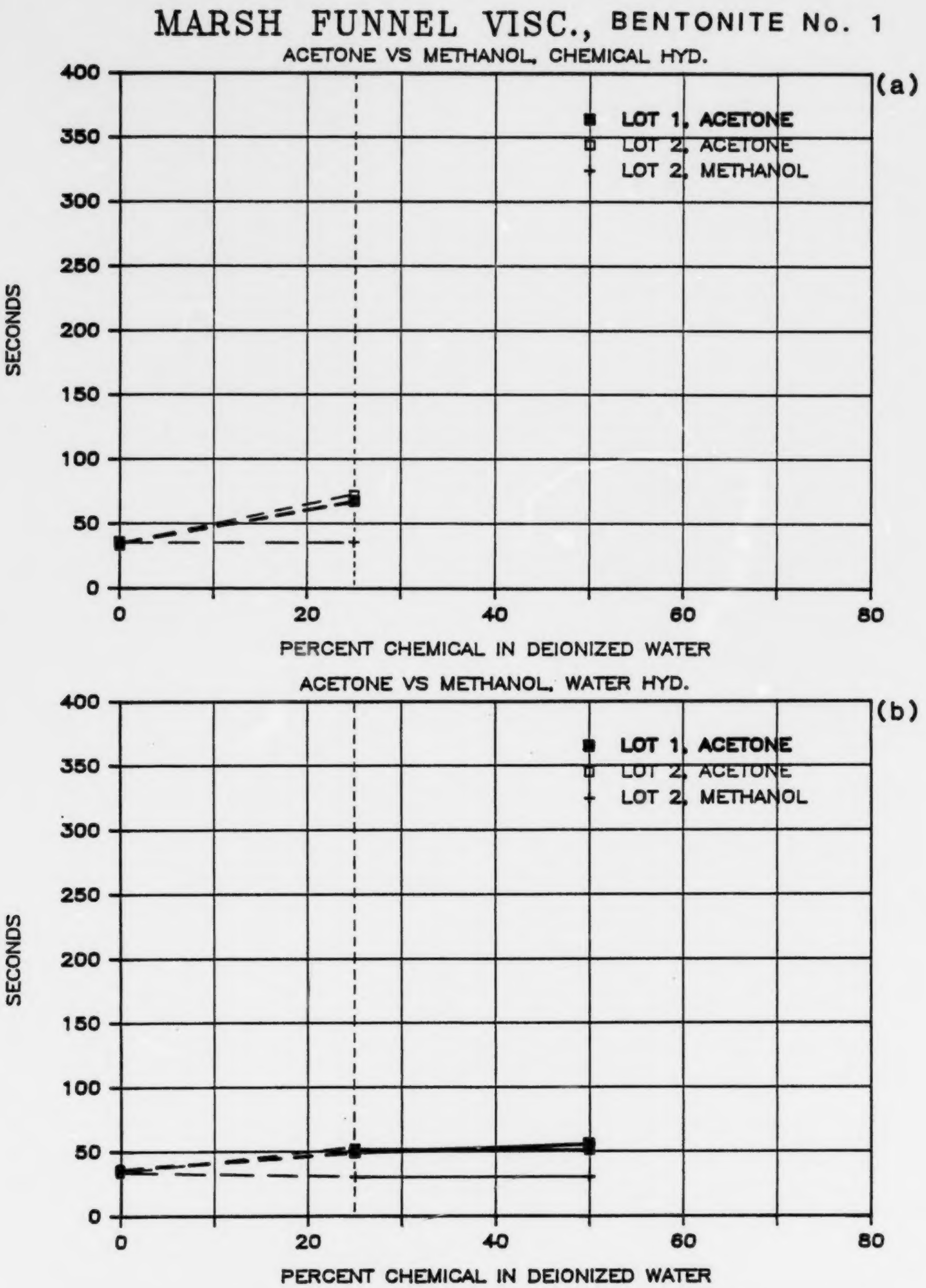


Figure 4: Secondary test results for unaltered bentonite no. 1; (a) "chemically" hydrated, (b) water hydrated

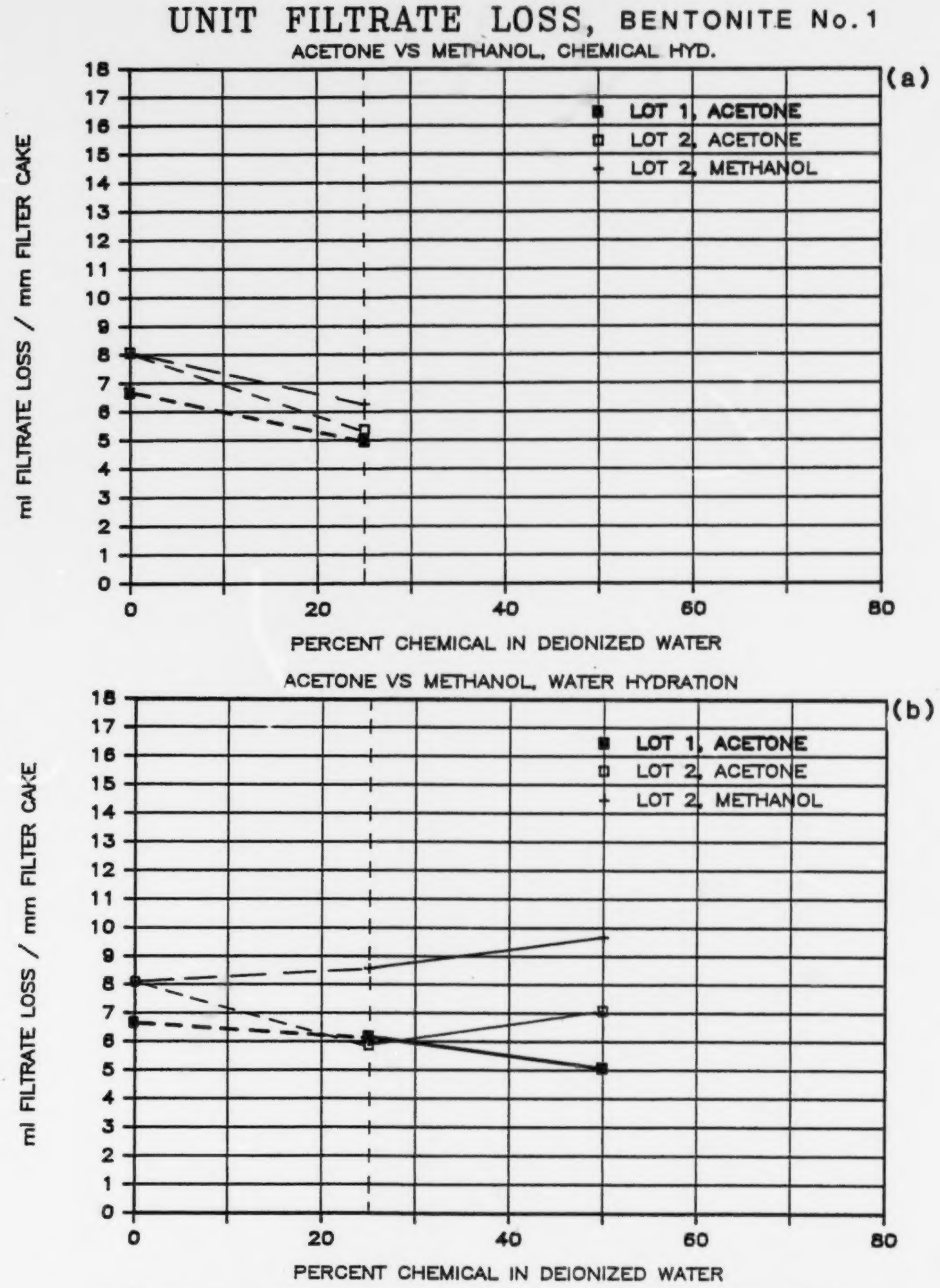


Figure 5: Secondary test results for unaltered bentonite no. 1; (a) "chemically" hydrated, (b) water hydrated

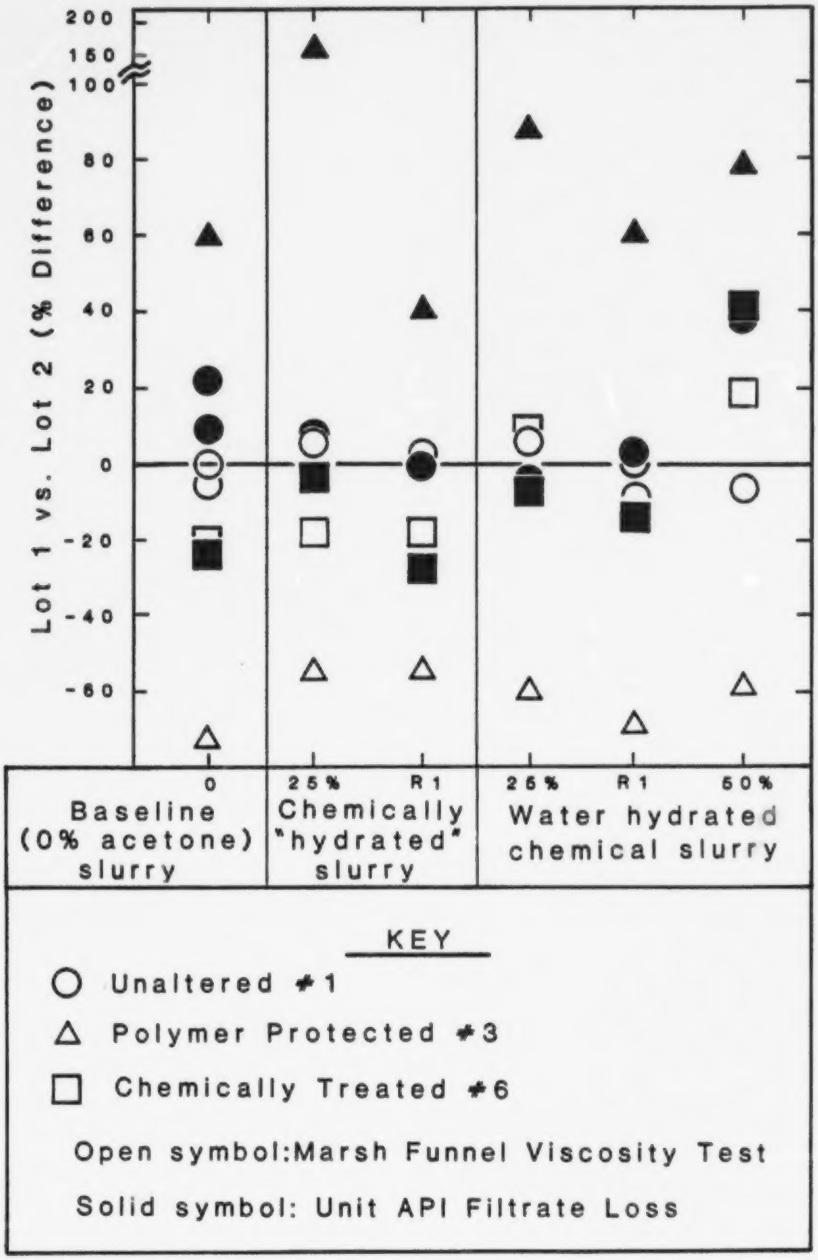


Figure 6: Variablility of different lots of three bentonite products

PRIMARY TESTS

Slurry Form

Tabulated primary test data in Appendix A are presented by specific bentonite. The tables are useful not only as a record of all results for the particular bentonite, but serve to indicate the range of tests performed, the various slurry hydration cases and acetone concentrations tested, and the level of test replication. Conversely, plotted primary test data in Appendix A are presented by indicator test. The plots can be used to compare the performance of various bentonites for each indicator test and, more importantly, to make an initial assessment of the degree to which bentonite response can be grouped by type for each test.

Appendix table A-11 is reproduced herein as Table 7 as an example of tabulated primary test data. Note that results for the baseline slurry (0% acetone) and chemically "hydrated" slurries are presented on the first page, and data for the water hydrated acetone slurry is shown on the continuation page. In all cases, the designations "R_1" and "R_2" indicate the first and second replications of the particular test condition.

Appendix figure A-1 is likewise reproduced herein as Figures 7a through 7e. The plots contain results for the baseline, chemically "hydrated" and water hydrated cases for the specific bentonites noted. Baseline data appear as "zero" percent acetone in deionized water in each case. From 0% to a concentration of 25%, results for both chemically "hydrated" and water hydrated slurries are plotted. Above 25% acetone, data represent the water hydrated case only. Note that data for the water hydrated slurry at a 75% acetone concentration may not be comparable with data for lesser acetone concentrations due to necessary modification of the slurry batching procedure for the water hydrated case. (It was not possible to mix a 25% deionized water - 75% acetone slurry having a 5% bentonite concentration on a dry weight basis. All 75% acetone slurries were batched using water hydrated paste of lower initial water content).

In order to identify an indicator test to distinquish between the bentonite type classifications listed in Table 1, it is necessary that trends be consistent for all bentonites within each type-group and that the range of results for the various types do not overlap significantly. A quick overview of Figures 7a. through 7e. suggests the following for the marsh funnel viscosity test:

- Unaltered and physically altered types are practically identical for all slurries (baseline, chemically "hydrated", water hydrated).
- Polymer-protected/extended bentonites exhibit a marsh funnel viscosity in excess of 130 seconds in the chemically "hydrated" case at an acetone concentration of 15%.
- The physically altered/amine treated bentonite exhibits extreme viscosity (800 seconds, replicated as an outlier at 683 seconds) in the water hydrated case at an acetone concentration of 50%.

TABLE 7. PRIMARY INDICATOR TEST RESULTS (phase II)

Type: UNALTERED	CHEMICALLY 'HYDRATED' Slurry							
Bentonite: Id: 1	% ACETONE IN DEIONIZED WATER							
INDICATOR TEST	0 (BASELINE Slurry)	R_1	R_2	5	15	25	R_1	R_2
A. MARSH FUNNEL VISCOSITY (sec)	36.7	36.8	33.3	28.0	43.6	71.5	65.9	65.3
B. GEL STRENGTH (lb/100 ft^2)								
- 10 sec	0.8	1.0	0.5	0.0	7.5	14.0	12.0	11.0
- 10 min	6.8	9.0	4.0	0.0	9.0	21.0	22.0	24.0
C. APPARENT VISCOSITY (cP)	11.13	11.5	10.5	4.5	21.5	27.0	27.0	28.0
D. YIELD POINT (lb/100 ft^2)	4.8	5.0	4.0	1.0	13.0	20.0	18.0	20.0
E. PLASTIC VISCOSITY (cP)	9.3	9.0	9.0	4.0	15.0	17.0	18.0	18.0
F. FREE SWELL - 2 hr.	35.5	33.0	33.0	35.0	55.0	52.0	53.0	53.0
- 24 hr.	36.5	33.5	35.0	38.0	57.0	53.0	54.0	54.0
G. MUD WEIGHT (pcf)	64.8	64.8	64.5	63.1	63.3	63.3	63.3	63.0
H. SPECIFIC CONDUCTANCE (mmhos)	.942	.958	.877	.507	.707	.568	.516	.515
J. API FILTRATE LOSS								
(ml)	22.5	21.7	21.6	31.4	18.2	18.0	13.8	12.6
cake thickness [mm]	[2.3]	[2.7]	[2.5]	[1.8]	[2.9]	[3.2]	[1.6]	[1.7]
(ml/mm)	9.8	8.04	8.8	17.4	6.3	5.6	8.6	7.4
K. pH	9.8	9.8	9.8	10.2	9.9	1.0	9.7	9.9
Slurry Temperature (°C)	20.9	20.9	20.3	20.2	21.4	20.8	21.2	21.2
RUN:	1	2	3	4	5	6	7	8

NOTE: "Outlier" results in parentheses ( )
Slurry remixed immediately prior to test

(continued)

TABLE 7. (continued)

Type: UNALTERED	WATER HYDRATED Chemical Slurry						
Bentonite: Id: 1	% ACETONE IN DEIONIZED WATER						
INDICATOR TEST	5	15	25	R_1	R_2	50	75*
A. MARSH FUNNEL VISCOSITY (sec)	35.9	39.5	39.3	42.6	47.3	51.7	32.1
B. GEL STRENGTH (lb/100 ft^2)							
- 10 sec	1.0	1.5	2.0	3.0	5.0	9.0	0.5
- 10 min	5.0	15.0	14.0	2.0	15.0	7.0	3.0
C. APPARENT VISCOSITY (cP)	13.5	17.0	18.5	19.0	20.5	22.0	8.5
D. YIELD POINT (lb/100 ft^2)	11.0	8.0	11.0	12.0	9.0	12.0	3.0
E. PLASTIC VISCOSITY (cP)	5.0	13.0	13.0	13.0	16.0	16.0	7.0
F. FREE SWELL - 2 hr.	--	--	--	--	--	--	--
- 24 hr.	--	--	--	--	--	--	--
G. MUD WEIGHT (pcf)	64.0	63.8	63.0	62.8	63.0	60.8	57.0
H. SPECIFIC CONDUCTANCE (mmhos)	.770	.661	.507	.528	.604	.387	.0722
J. API FILTRATE LOSS							
(ml)	18.3	17.0	15.8	15.7	16.0	13.7	20.2
cake thickness [mm]	[2.5]	[2.5]	[2.7]	[2.7]	[2.5]	[2.6]	[2.8]
(ml/mm)	7.3	6.8	5.8	5.8	6.4	5.3	7.2
K. pH	9.2	9.8	9.8	9.9	10.1	9.0	8.9
Slurry Temperature (°C)	22.0	22.2	22.4	22.4	22.3	21.3	21.2
RUN:	9	10	11	12	13	14	15

NOTE: "Outlier" results in parentheses ( )
Slurry remixed immediately prior to test
*A paste of lower moisture content was used to prepare the 75% slurry

The same may be true for the chemically "hydrated" case, although this case was not run (trends are consistent up to 25% acetone).

- Slurries for the chemically treated bentonites generally have the lowest response of all chemically "hydrated" slurries (less than 40 seconds).

The above observations suggest that the marsh funnel viscosity test may be a useful tool to identify the physically altered/amine treated bentonite or the polymer protected/extended bentonites. This particular test would be less than ideal, however, since more than one acetone concentration and slurry hydration case would need to be run and the test fails to permit identification of the other three bentonite types, regardless of acetone concentration or slurry hydration case.

The "ideal" indicator test for type-distinction should permit bentonite classification on the basis of test results for a single set of test conditions (acetone concentration and hydration case). A review of other plotted primary test results in Appendix A (Figures A-1 through A-8) suggests that no such ideal test exists within the scope of tests evaluated during this study. The figures are useful as a general resource describing the range of responses of the various bentonite types for selected (Phase II) indicator tests, but they do not readily indicate which of the tests is best or most nearly "ideal" for type-distinction.

Other Forms

The testing of bentonite products in other than slurry form was limited to those tests so identified on Table 2. Of those listed, the free swell and modified swell tests on powdered bentonite were judged to be the most promising and were therefore investigated in more than one phase of the study. Of these two tests, the modified swell was clearly superior due to a lower degree of subjectivity in the measurement of volumetric swell. For this reason, discussion herein is limited to the modified swell test.

The modified swell test involves the measurement of one-dimensional (vertical) swell using a dial gauge and a conventional consolidometer, both before and after chemical "modification" of the bentonite. Chemicals used as modifying agents included acetone, methanol, and xylene. The procedure is detailed as SLP No. EX-02 in Appendix D; the highlights are as follows:

- Determine baseline swell characteristics of selected powdered bentonites using deionized water.
- Mix selected bentonites with selected full-strength chemicals (essentially comparable to the chemically "hydrated" case for testing of bentonite slurries).
- Allow chemical to volatilize in fume hood overnight.
- Determine swell characteristics for an equivalent dry weight of "modified" bentonite using deionized water.

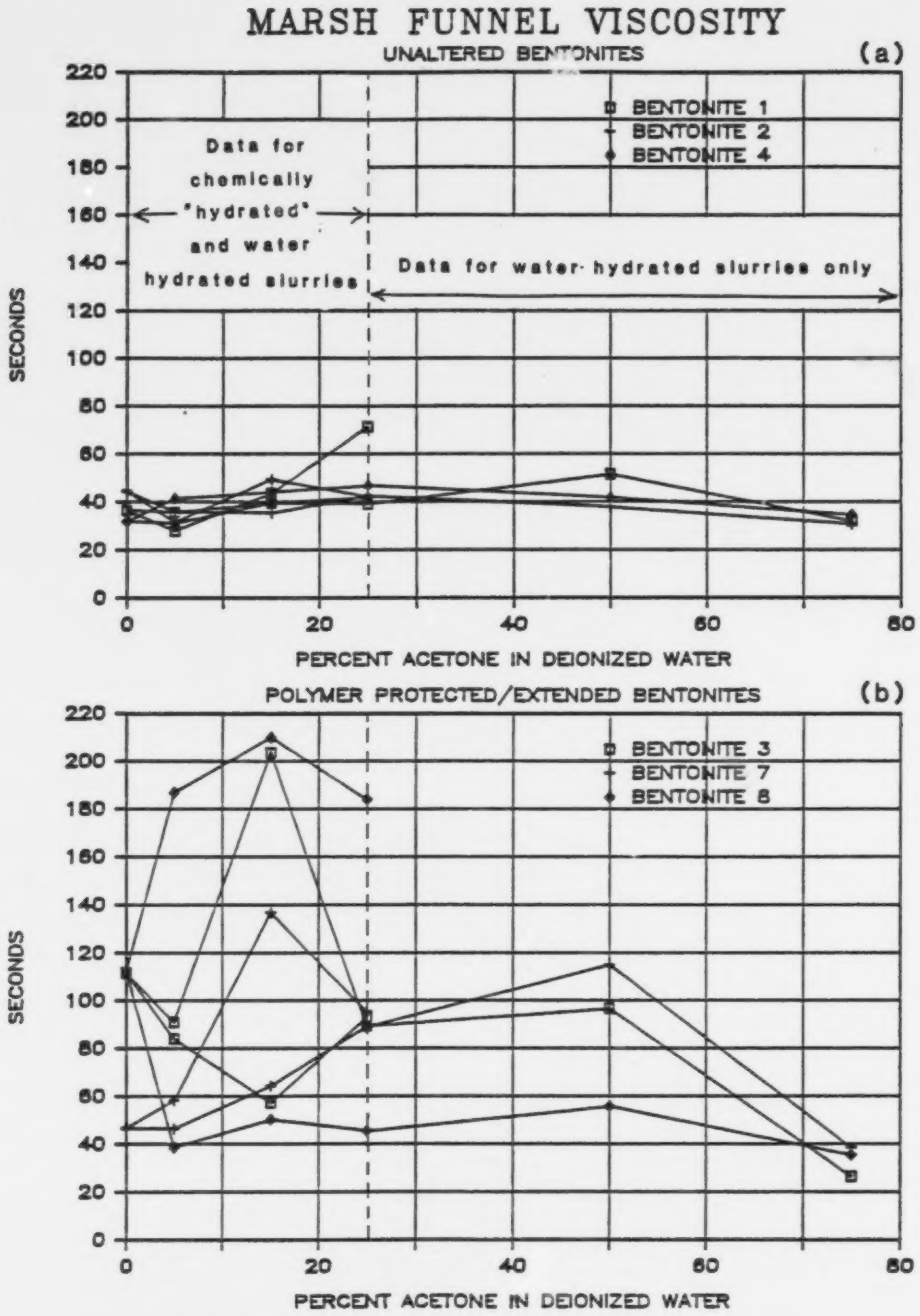
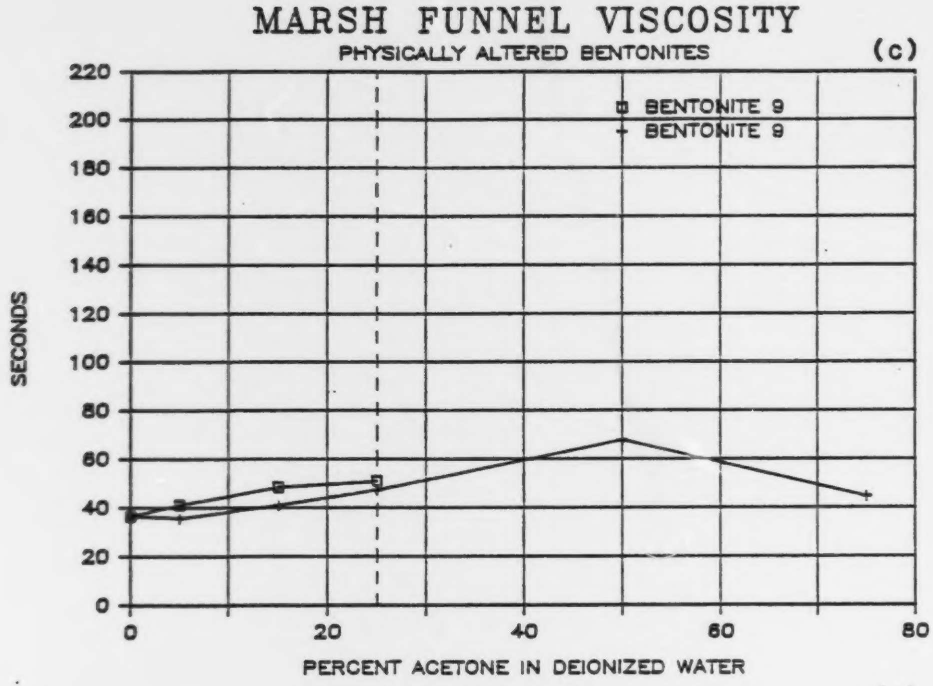


Figure 7 : Selected Phase II primary indicator test results for Marsh Funnel Viscosity test.



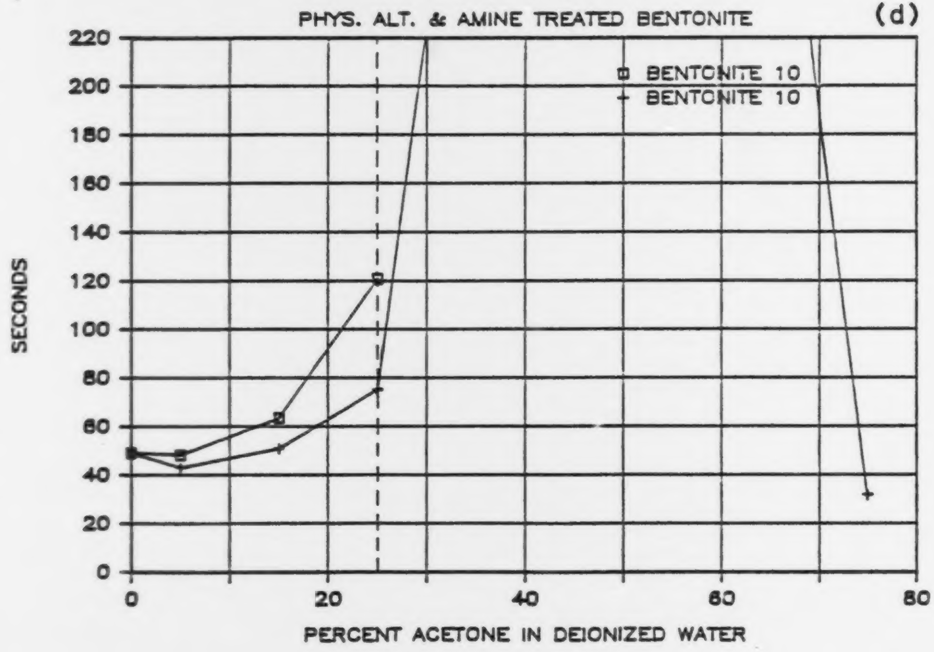


Figure 7 : (continued)

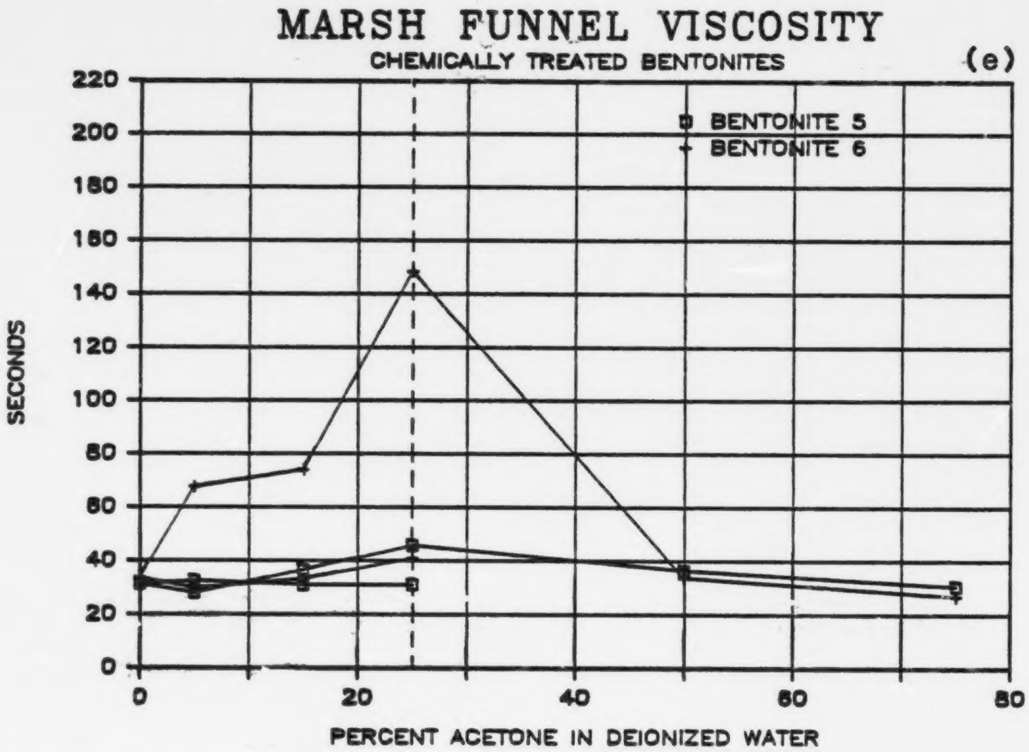


Figure 7. (Continued)

A total of forty-eight separate tests were performed on seven different bentonites during the latter two phases of this project. Tabulated results for these tests appear in appended tables A-21 through A-24 and C10 through C-20.

Initial (Phase II) results for four of the bentonites are shown in Figures 8a through 8d. Note that baseline (0% chemical) conditions were replicated in all cases to validate results observed for modified cases.

To facilitate evaluation, initial and replicate baseline results as well as results for the methanol case have been highlighted. It appears that the highlighted curves constitute signatures which can be used to differentiate between three of the four bentonites. Based upon the order and relative position of the baseline and methanol curves, bentonite No. 3 is distinguishable from bentonite No. 1 (reversal of order). Bentonite No. 6 can be distinquished from No. 1 for the same reason, and can be distinguished from No. 3 in terms of a much lower level of response, which partially overlaps the acetone and xylene curves. Differentiation between bentonite Nos. 1 and 9 is not possible.

These observations are reinforced by the smooth, regular shape of the curves and the level of success in replicating baseline results. Small differences in baseline curves for a given bentonite could be due to slight variations in initial water content of the bentonite samples. The effect of initial water content on the swell signature was investigated (Phase III) prior to further modified swell testing of other bentonites.

Figure 9 depicts different baseline curves generated at different initial water contents for one (presumabnly typical bentonite. Each test condition was replicated once. The data indicate an inverse relationship between initial water content and the total 7-hour swell for this bentonite. The relationship is more clearly illustrated by viewing total 7-hour swell as a function of initial bentonite water content in Figure 10. (Data in Figure 10 for bentonite Nos. 3 and 6 are discussed later.)

The initial water content of bentonite samples in subsequent (Phase III) testing was held constant, within practical limits (8.16% to 8.58% range). The rationale was that a relatively low initial wate content should maximize total swell, thereby enhancing type-distinction. A secondary consideration was tha a uniform initial water content could be more readily achieved by drying the bentonite than by wetting it.

Earlier (Phase II) test results suggested that the baseline and methanol curves were most useful for type-distinction. for this reason, and practical schedule considerations, acetone and xylene were omitted from the final phase of testing.

Figures 11 through 13 present results for six bentonites tested using water (baseline) and methanol at nearly constant initial water content. All baseline tests were replicated. The top figure on each page (a) shows new replicate results for a specific bentonite previously tested; the bottom figure on each page (b) shows results for a new bentonite of the same type-group.

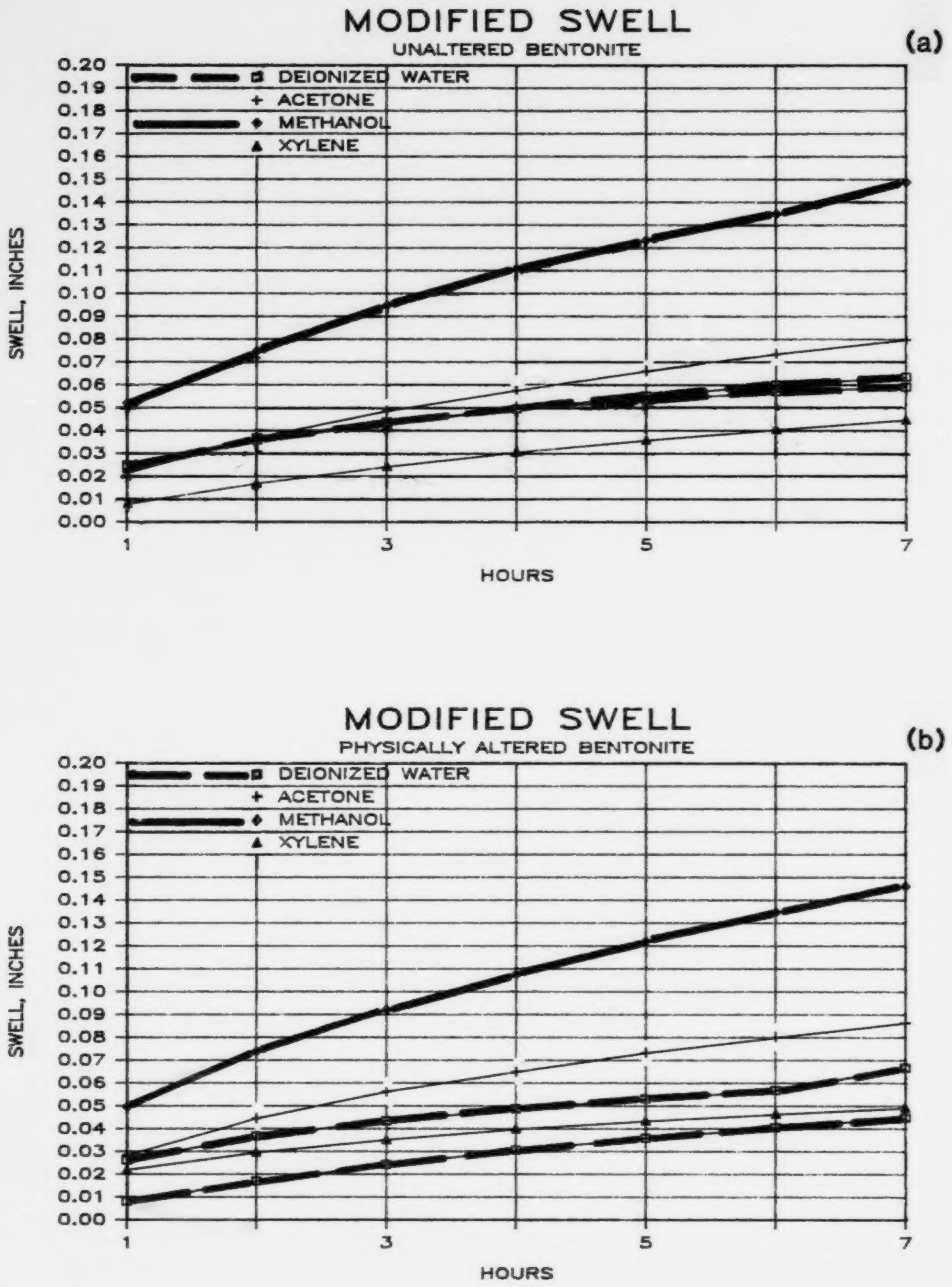
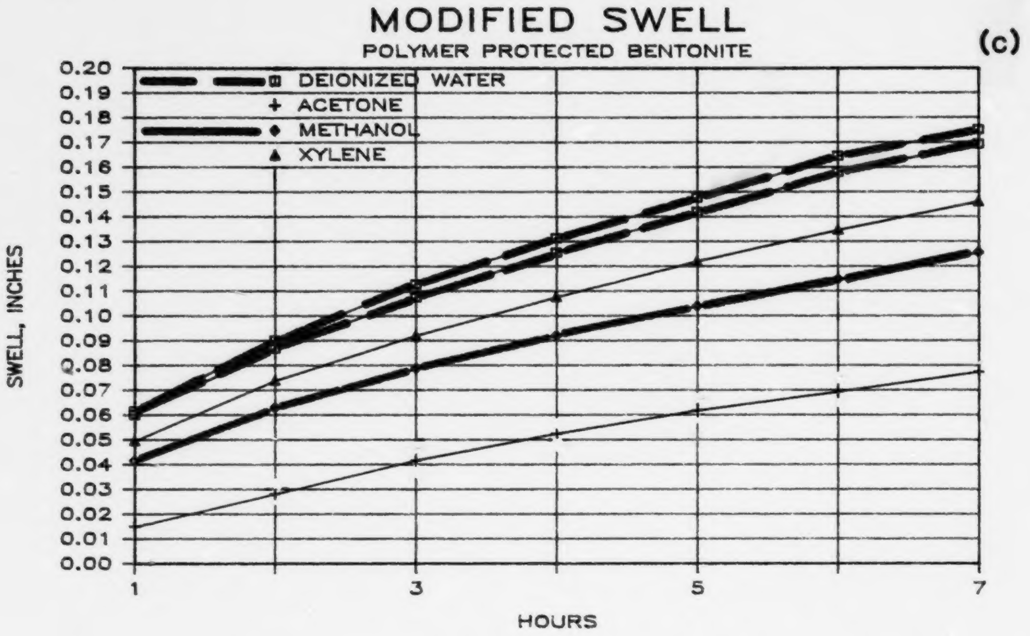


Figure 8: Phase II modified swell test results



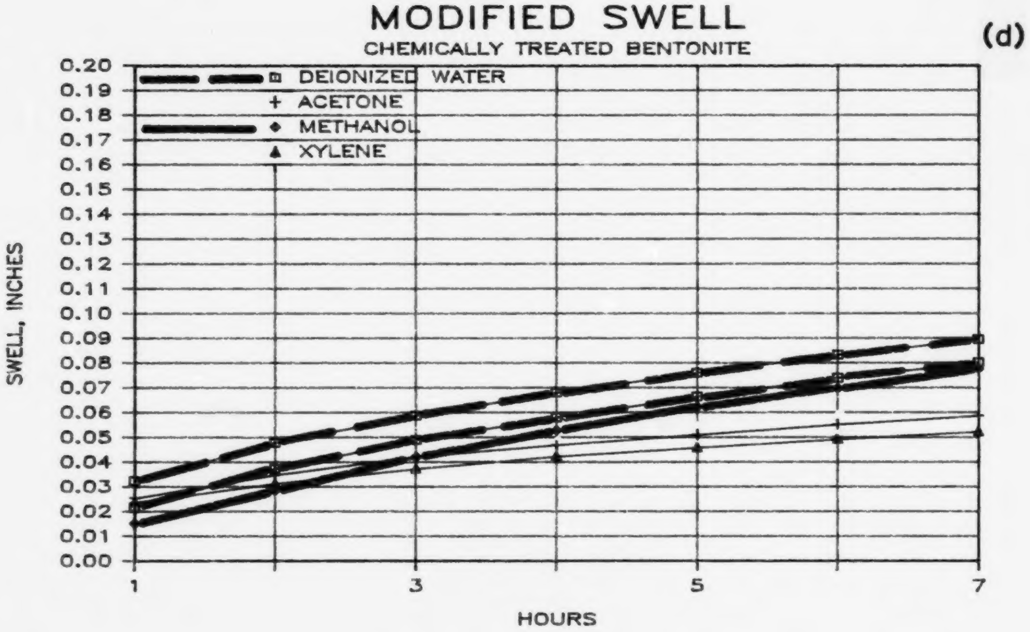


Figure 8: (continued)

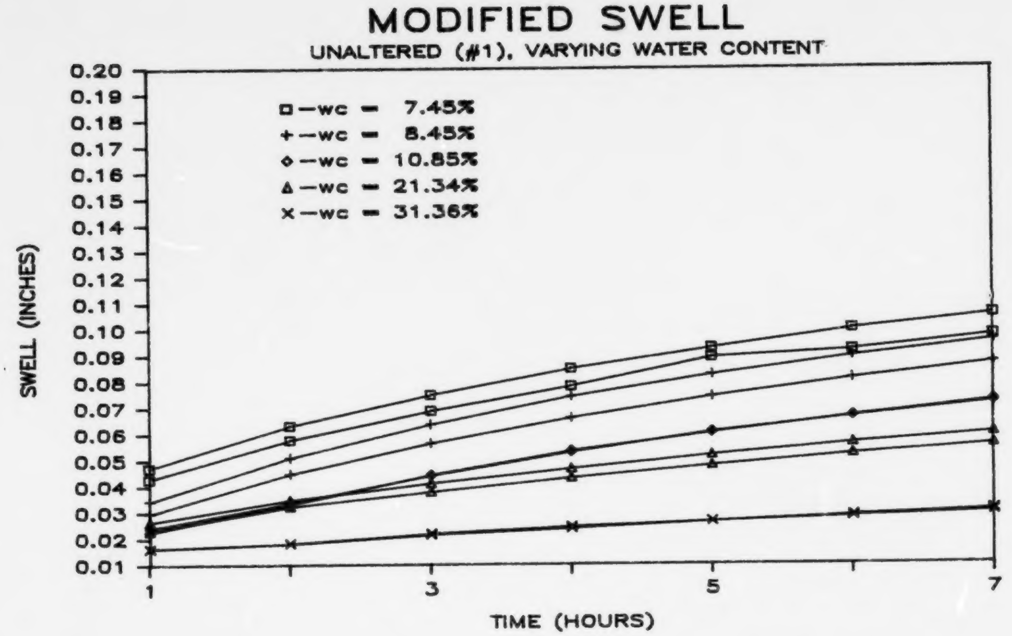


Figure 9: Baseline swell curves for different initial water contents of unaltered bentonite no. 1

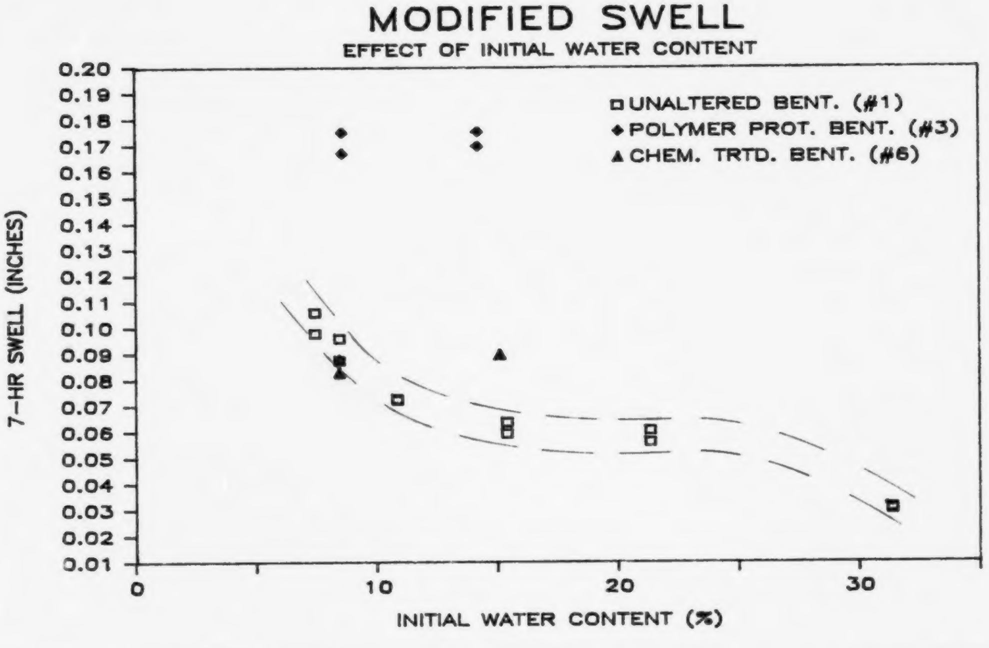


Figure 10: Total 7-hour swell of three bentonites as a function of initial water content

Results for each type-pair on these plots are very consistent in terms of magnitude and position of the signature curves (all axes scaled the same). The most striking difference is between the methanol curves shown here, and those resulting from earlier testing for unaltered bentonite No. 1 (compare Figures 8a and 11a). Initial testing of bentonite No. 1 involved an initial water content of about 15 percent; whereas subsequent replicate testing was at an initial water content of about 8.5 percent. It appears that lower initial water content had the effect of greatly suppressing the methanol response and perhaps slightly increasing the average baseline response for this bentonite.

Comparison of comparable data for the polymer protected and chemically treated bentonites does not suggest a similar effect. The baseline and methanol curves for these two types appear to be insensitive to differences in initial bentonite water content. This relationship is more clearly illustrated in Figure 10, which also contains limited data for these two bentonites (data from "initial" and "final" testing in research phases II and III, respectively). The reason for the apparent insensitivity is not known. Perhaps the polymer or chemical agent in each case binds water molecules to the bentonite more tightly and thereby protects it from chemical attack.

The foregoing data for the modified swell test considered as a whole are inconclusive in terms of bentonite type-distinction. It appears, however, that some degree of distinction between the types herein may be possible in the case of relatively high initial water content (15 percent ±). Nevertheless, the data in Figure 10 suggest two additional tentative conclusions.

- The swell potential of polymer protected bentonites may be as much as twice that of unaltered or chemically treated bentonites.
- The swell potential of both the polymer protected and chemically treated bentonites appears to be independent of initial water content.

The latter tentative conclusion may have particular design or QA relevance even though a quantitative relationship between swell potential and hydraulic conductivity has not been established.

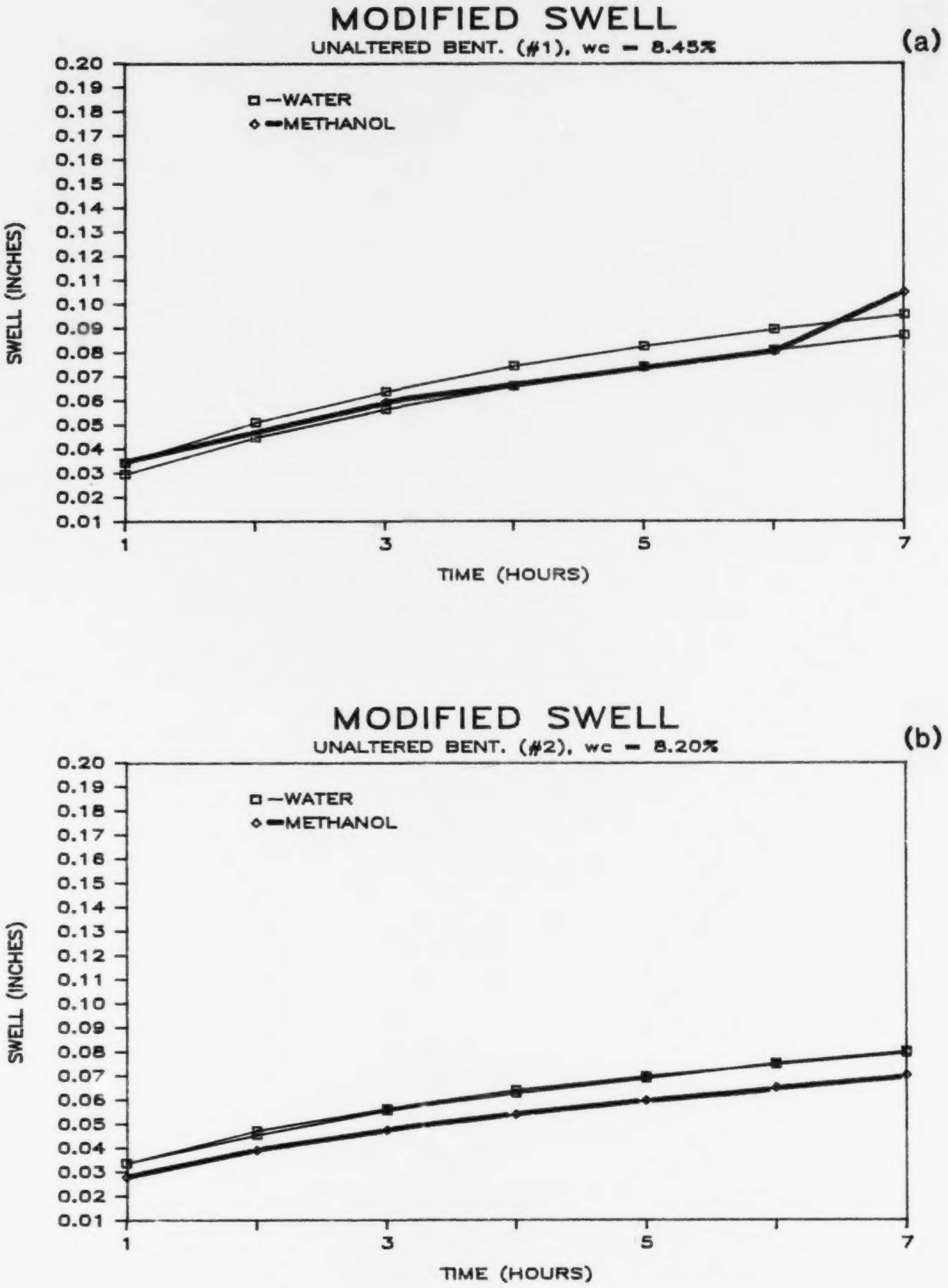


Figure 11: Modified swell test results; (a) Phase II replicate (b) Phase III results for a different bentonite of the same type

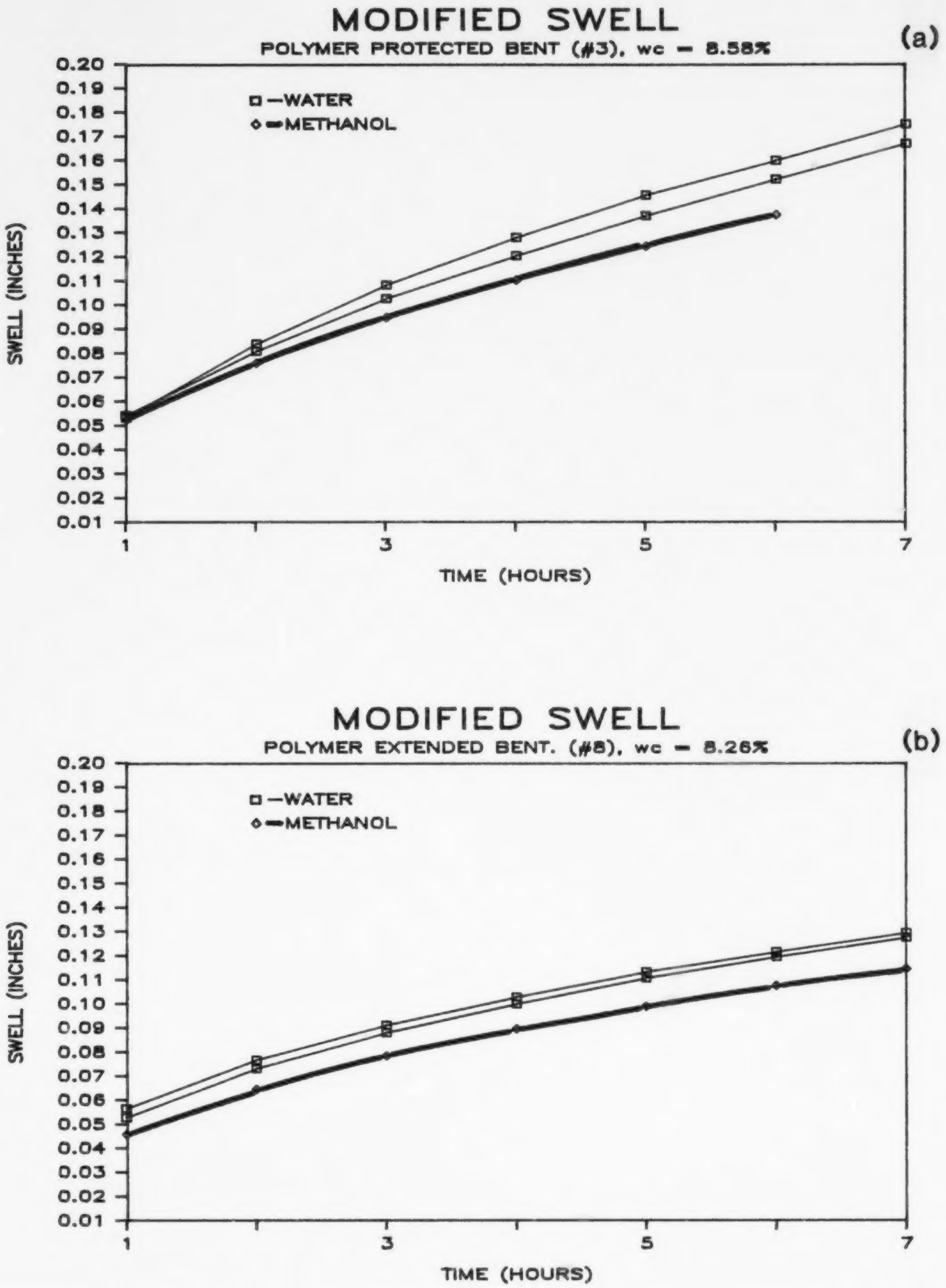


Figure 12: Modified swell test results; (a) Phase II replicate (b) Phase III results for a different bentonite of the same type

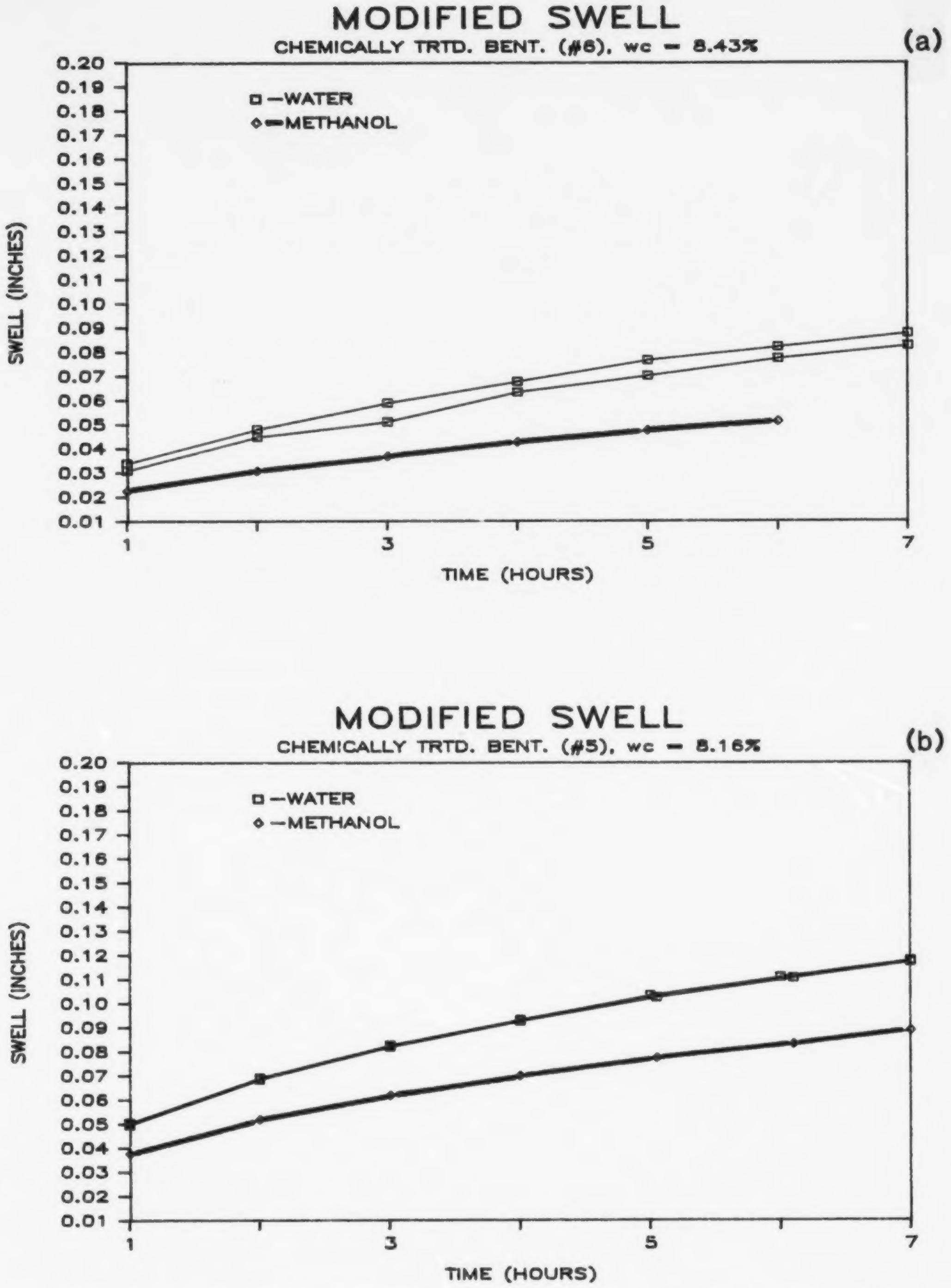


Figure 13: Modified swell test results; (a) Phase II replicate (b) Phase III results for a different bentonite of the same type

ANALYSIS OF VARIANCE

Much of the third phase of this study was devoted to the performance of correlation tests to augment the indicator test data base for statistical analysis and to generate data to evaluate a potential relationship between indicator test parameters and hydraulic conductivity.

Type-distinction results described herein are limited to unaltered, polymer protected/extended and chemically treated types. Since the physically altered/amine treated bentonite types each comprised only one sample, they were not considered in the statistical evaluation of type-distinction potential. Test procedures included in the analysis were limited to marsh funnel viscosity, tests employing the rotational viscometer (gel strength, yield point, apparent viscosity and plastic viscosity), and both the standard and "unit" API filtrate loss tests.

The statistical data base comprises data from all three research phases for three slurry cases: baseline, 25% acetone chemically "hydrated", 25% acetone water hydrated. The analysis was limited to these slurry cases because of the relatively high level of test replication. The data base also includes the results of secondary tests described earlier (lot 1 vs. lot 2) and therefore includes product variability as well as operator and batching variability.

A one-way analysis of variance was performed using the personal computer version of MINITAB (release 82.1.1, copyright Minitab, Inc., 1984). The implicit underlying assumptions are:

- random sample for each population
- normal distribution of each population
- all of the populations have the same variance (σ^2)

As defined for this analysis, a population consists of all results for a single combination of indicator test, bentonite type, and slurry hydration case. The first two assumptions are not explicitly known but are presumed to be satisfied within the limited scope of this investigation. The third assumption is not critical if each population is about the same size. The analysis is designed to answer the question, "do the various population means differ any more than we would expect from just random variation?"

Results for each indicator test are presented by slurry hydration case in Figures 14 through 21. In each case, the three entries in the "level" column represent the three type-groups analyzed (U = unaltered, P = polymer protected/extended, C=chemically treated; additional designations irrelevant to discussion).

As an example interpretation of the data, consider results for the baseline slurry case in Figure 14a. The data on the top half of the output constitute an analysis of variance table. "Factor" and "Error" represent the two primary sources of variation; that due to differences between the "levels" (types of bentonite), and that due to differences within the "levels", repectively. Each source of variation is followed by the associated degrees of freedom (DF), its corresponding sum of squares (SS), and mean square (MS) variation based upon analysis of the raw data (not shown). The "F" statistic is simply the ratio of the two mean square values and reflects the relative amount of variability attributable to the two sources. In the example, the F value of 11.34 indicates that the between-type variability is more than eleven times as great as the within-type variability. Whether or not this is significant in term of type-distinction can be determined from a table of critical F values for the known degrees of freedom at a chosen level of confidence.

In the example, the critical F value at a confidence level of 95 percent (F(95)) is 3.23. Since the computed F value for this comparison exceeds the critical value, the between-type variation is significantly greater than the within-type variation and some degree of type-distinction should therefore be possible. Plotted confidence intervals around the means of the three levels or types, indicate that it is possible to distinguish the polymer protected/extended bentonites from the other two types using the marsh funnel viscosity test on a baseline slurry. This is also true for the chemically "hydrated" slurry (25% acetone), but is not true for the water hydrated chemical slurry.

Suggested Test Protocol

Three generalizations are pertinent after review of the output for the other indicator tests and slurry cases:

- Several combinations of test procedure and slurry case permit identification of the polymer protected/extended bentonite type.

- No test procedure permits clear distinction of the three bentonite types in the water hydrated 25% acetone slurry case.

- There is no clear advantage in using the marsh funnel viscosity test, API filtrate loss test, or unit filtrate loss test for type-distinction; ie., tests performed using the rotational viscometer alone generally appear to yield as much, if not more, capacity to distinguish between the three bentonite types

Considering only the five tests performed on the rotational viscometer, identification of the best test for type distinction could be achieved by computing F/F(95); the best test having the largest ratio. This might be misleading however as in the case of the yield point test on chemically "hydrated" slurries (Figure 18b). Here the large F value (actually the largest of any test) is clearly influenced by the response of the polymer protected/extended bentonites since the ranges of the other two types overlap. Furthermore, numerical analysis is unnecessary since selection can be

MARSH FUNNEL VISCOSITY TESTS

(a)

BASELINE SLURRY

```
ANALYSIS OF VARIANCE
SOURCE      DF        SS        MS       F              F(95)
FACTOR       2      7170      3585     11.34            3.23
ERROR       40     12649       316
TOTAL       42     19819
                                  INDIVIDUAL 95 PCT CI'S FOR MEAN
                                  BASED ON POOLED STDEV
LEVEL        N      MEAN     STDEV  ---+---------+---------+---------+---
UA0         15     34.96      4.03    (-------*------)
PA0         16     60.24     28.72                       (-----*-----)
CA0         12     31.98      2.05  (--------*------)
                                    ---+---------+---------+---------+---
POOLED STDEV = 17.78                  28        42        56        70
```

(b)

CHEM. "HYDRATED" SLURRY

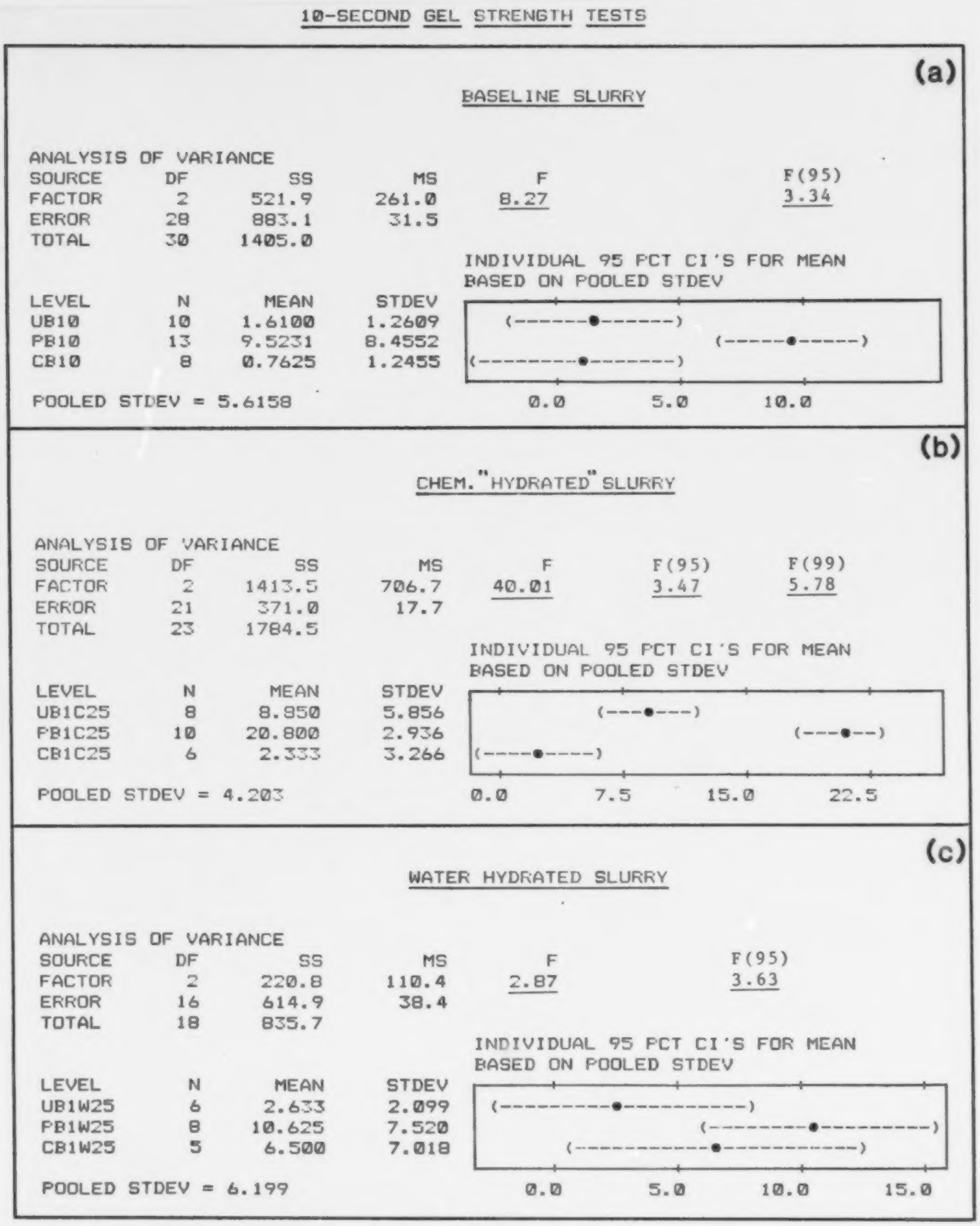
```
ANALYSIS OF VARIANCE
SOURCE      DF        SS        MS       F              F(95)
FACTOR       2     17509      8755     17.64            3.2
ERROR       39     19350       496
TOTAL       41     36859
                                  INDIVIDUAL 95 PCT CI'S FOR MEAN
                                  BASED ON POOLED STDEV
LEVEL        N      MEAN     STDEV  ----+---------+---------+---------+--
UAC25       15     59.10     14.05         (-----*----)
PAC25       15     94.17     33.39                          (-----*-----)
CAC25       12     45.55      9.43  (------*-----)
                                    ----+---------+---------+---------+--
POOLED STDEV = 22.27                   40        60        80       100
```

(c)

WATER HYDRATED SLURRY

```
ANALYSIS OF VARIANCE
SOURCE      DF        SS        MS       F              F(95)
FACTOR       2      2705      1353      1.91            3.37
ERROR       26     18403       708
TOTAL       28     21109
                                  INDIVIDUAL 95 PCT CI'S FOR MEAN
                                  BASED ON POOLED STDEV
LEVEL        N      MEAN     STDEV  ---+---------+---------+---------+---
UAW25       10     45.31      4.68   (---------*----------)
PAW25       10     67.89     28.76               (---------*----------)
CAW25        9     51.59     36.68      (---------*----------)
                                    ---+---------+---------+---------+---
POOLED STDEV = 26.61                  32        48        64        80
```

Figure 14: Results of one-way analysis of variance on all marsh funnel viscosity data for three slurry cases.



```
                    10-SECOND GEL STRENGTH TESTS
```

```
                                                                (a)
                                    BASELINE SLURRY

ANALYSIS OF VARIANCE
SOURCE      DF        SS        MS         F                  F(95)
FACTOR       2     521.9     261.0      8.27                   3.34
ERROR       28     883.1      31.5
TOTAL       30    1405.0
                                    INDIVIDUAL 95 PCT CI'S FOR MEAN
                                    BASED ON POOLED STDEV
LEVEL        N      MEAN     STDEV  ----+---------+---------+---------
UB10        10    1.6100    1.2609     (------*------)
PB10        13    9.5231    8.4552                     (-----*-----)
CB10         8    0.7625    1.2455  (--------*-------)
                                    ----+---------+---------+---------
POOLED STDEV = 5.6158                  0.0       5.0      10.0
```

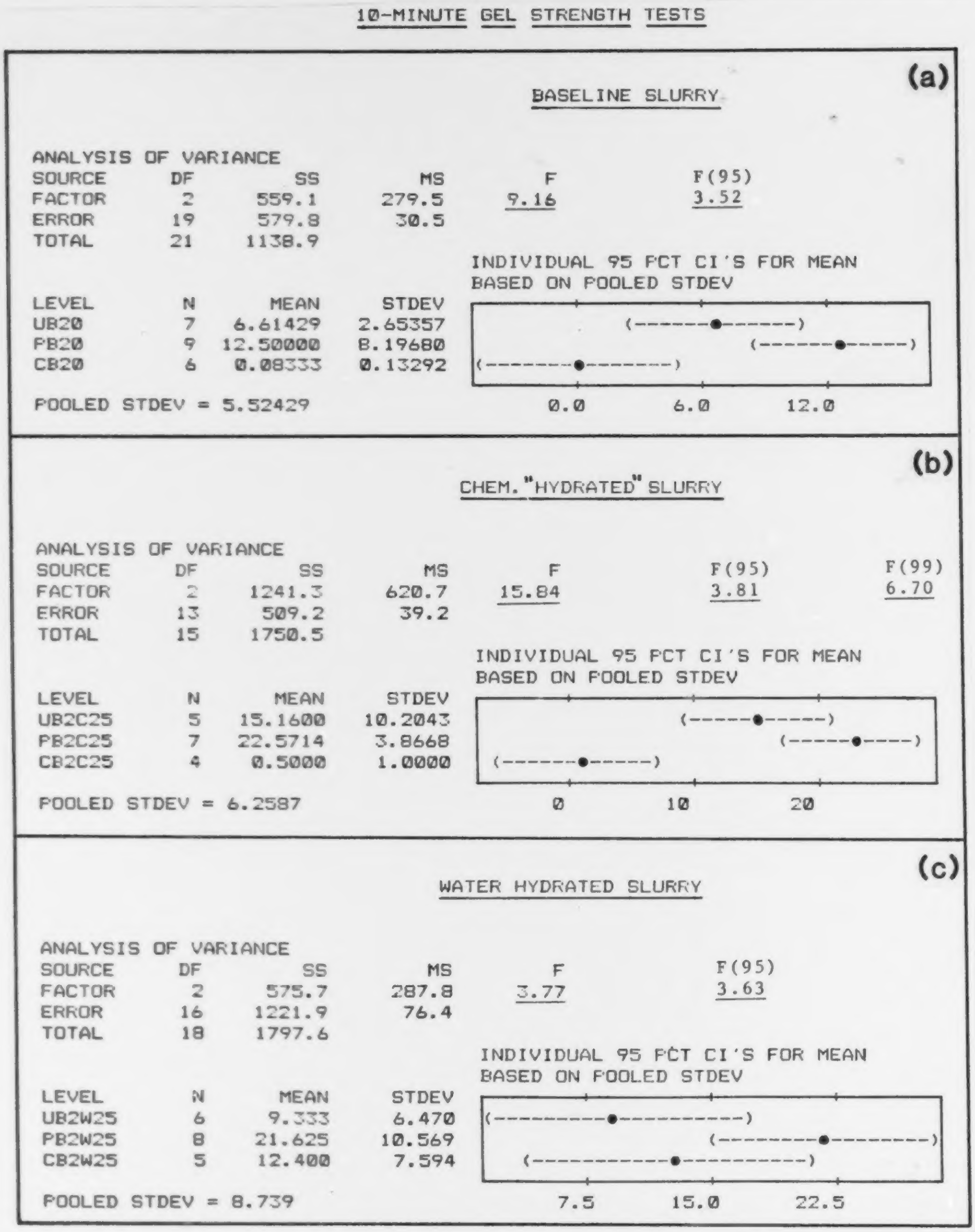
```
                                                                (b)
                                 CHEM."HYDRATED" SLURRY

ANALYSIS OF VARIANCE
SOURCE      DF        SS        MS         F       F(95)      F(99)
FACTOR       2    1413.5     706.7     40.01        3.47       5.78
ERROR       21     371.0      17.7
TOTAL       23    1784.5
                                    INDIVIDUAL 95 PCT CI'S FOR MEAN
                                    BASED ON POOLED STDEV
LEVEL        N      MEAN     STDEV  --+---------+---------+---------+--
UB1C25       8     8.850     5.856            (---*---)
PB1C25      10    20.800     2.936                         (---*--)
CB1C25       6     2.333     3.266  (----*----)
                                    --+---------+---------+---------+--
POOLED STDEV = 4.203                0.0       7.5      15.0      22.5
```

```
                                                                (c)
                                  WATER HYDRATED SLURRY

ANALYSIS OF VARIANCE
SOURCE      DF        SS        MS         F              F(95)
FACTOR       2     220.8     110.4      2.87               3.63
ERROR       16     614.9      38.4
TOTAL       18     835.7
                                    INDIVIDUAL 95 PCT CI'S FOR MEAN
                                    BASED ON POOLED STDEV
LEVEL        N      MEAN     STDEV  ------+---------+---------+---------+
UB1W25       6     2.633     2.099   (---------*-----------)
PB1W25       8    10.625     7.520                  (---------*---------)
CB1W25       5     6.500     7.018         (-----------*------------)
                                    ------+---------+---------+---------+
POOLED STDEV = 6.199                     0.0       5.0      10.0      15.0
```

Figure 15: Results of one-way analysis of variance on all 10-second gel strength data for three slurry cases.



```
                         10-MINUTE GEL STRENGTH TESTS

                                                                      (a)
                                        BASELINE SLURRY

ANALYSIS OF VARIANCE
SOURCE      DF        SS         MS          F             F(95)
FACTOR       2     559.1      279.5       9.16             3.52
ERROR       19     579.8       30.5
TOTAL       21    1138.9
                                    INDIVIDUAL 95 PCT CI'S FOR MEAN
                                    BASED ON POOLED STDEV
LEVEL        N      MEAN      STDEV ---------+---------+---------+-
UB20         7   6.61429    2.65357          (------*------)
PB20         9  12.50000    8.19680                    (------*-----)
CB20         6   0.08333    0.13292 (-------*-------)
                                    ---------+---------+---------+-
POOLED STDEV = 5.52429                     0.0       6.0      12.0
```

```
                                                                      (b)
                                   CHEM."HYDRATED" SLURRY

ANALYSIS OF VARIANCE
SOURCE      DF        SS         MS          F             F(95)       F(99)
FACTOR       2    1241.3      620.7      15.84             3.81        6.70
ERROR       13     509.2       39.2
TOTAL       15    1750.5
                                    INDIVIDUAL 95 PCT CI'S FOR MEAN
                                    BASED ON POOLED STDEV
LEVEL        N      MEAN      STDEV -------+---------+---------+-------
UB2C25       5   15.1600    10.2043              (-----*-----)
PB2C25       7   22.5714     3.8668                      (-----*----)
CB2C25       4    0.5000     1.0000 (------*-----)
                                    -------+---------+---------+-------
POOLED STDEV = 6.2587                      0        10        20
```

```
                                                                      (c)
                                   WATER HYDRATED SLURRY

ANALYSIS OF VARIANCE
SOURCE      DF        SS         MS          F             F(95)
FACTOR       2     575.7      287.8       3.77             3.63
ERROR       16    1221.9       76.4
TOTAL       18    1797.6
                                    INDIVIDUAL 95 PCT CI'S FOR MEAN
                                    BASED ON POOLED STDEV
LEVEL        N      MEAN      STDEV -------+---------+---------+-------
UB2W25       6     9.333      6.470 (---------*----------)
PB2W25       8    21.625     10.569              (--------*--------)
CB2W25       5    12.400      7.594   (-----------*----------)
                                    -------+---------+---------+-------
POOLED STDEV = 8.739                      7.5      15.0      22.5
```

Figure 16: Results of one-way analysis of variance on all 10-minute gel strength data for three slurry cases.

APPARENT VISCOSITY TESTS

(a)

```
                                BASELINE SLURRY

ANALYSIS OF VARIANCE
SOURCE      DF        SS          MS          F            F(95)        F(99)
FACTOR       2    1526.0       763.0      19.36             3.34         5.45
ERROR       28    1103.5        39.4
TOTAL       30    2629.6
                                      INDIVIDUAL 95 PCT CI'S FOR MEAN
                                      BASED ON POOLED STDEV
LEVEL        N      MEAN       STDEV  ------+---------+---------+--------
UC0         10    11.950       3.653            (----*----)
PC0         13    23.631       9.023                            (----*---)
CC0          8     7.275       0.960  (-----*-----)
                                      ------+---------+---------+--------
POOLED STDEV = 6.278                        7.5      15.0      22.5
```

(b)

```
                             CHEM."HYDRATED"SLURRY

ANALYSIS OF VARIANCE
SOURCE      DF        SS          MS          F            F(95)        F(99)
FACTOR       2    1948.4       974.2      36.12             3.47         5.78
ERROR       21     566.4        27.0
TOTAL       23    2514.8
                                      INDIVIDUAL 95 PCT CI'S FOR MEAN
                                      BASED ON POOLED STDEV
LEVEL        N      MEAN       STDEV  -------+---------+---------+-------
UCC25        8     22.37        4.86             (----*----)
PCC25       10     36.40        6.10                             (----*---)
CCC25        6     14.72        3.62   (----*-----)
                                      -------+---------+---------+-------
POOLED STDEV =  5.19                        16.0      24.0      32.0
```

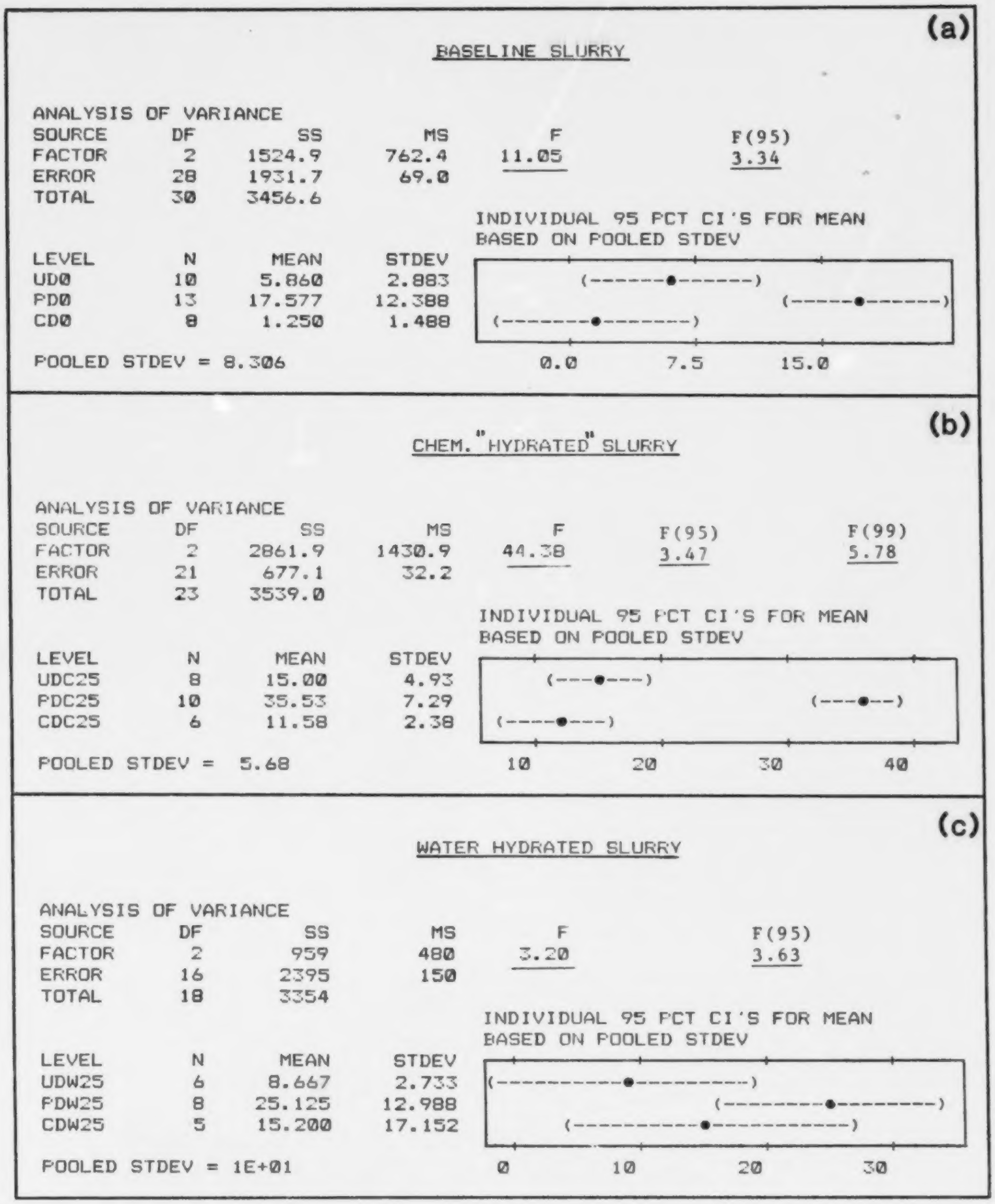
(c)

```
                              WATER HYDRATED SLURRY

ANALYSIS OF VARIANCE
SOURCE      DF        SS          MS          F            F(95)
FACTOR       2       887         444       2.43             3.63
ERROR       16      2926         183
TOTAL       18      3814
                                      INDIVIDUAL 95 PCT CI'S FOR MEAN
                                      BASED ON POOLED STDEV
LEVEL        N      MEAN       STDEV  -----+---------+---------+---------+-
UCW25        6     18.67        3.36  (---------*---------)
PCW25        8     34.31       13.16              (---------*-------)
CCW25        5     24.00       20.35     (----------*----------)
                                      -----+---------+---------+---------+-
POOLED STDEV = 13.52                      12        24        36        48
```

Figure 17: Results of one-way analysis of variance on all apparent viscosity data for three slurry cases.

YIELD POINT TESTS



(a)

```
                         BASELINE SLURRY

ANALYSIS OF VARIANCE
SOURCE      DF       SS         MS          F            F(95)
FACTOR       2   1524.9      762.4      11.05             3.34
ERROR       28   1931.7       69.0
TOTAL       30   3456.6
                                   INDIVIDUAL 95 PCT CI'S FOR MEAN
                                   BASED ON POOLED STDEV
LEVEL        N     MEAN      STDEV  ---------+---------+---------+-----
UD0         10    5.860      2.883         (-------•-------)
PD0         13   17.577     12.388                        (-----•-------)
CD0          8    1.250      1.488    (--------•--------)
                                    ---------+---------+---------+-----
POOLED STDEV = 8.306                       0.0      7.5      15.0
```

(b)

```
                      CHEM. "HYDRATED" SLURRY

ANALYSIS OF VARIANCE
SOURCE      DF       SS         MS          F         F(95)        F(99)
FACTOR       2   2861.9     1430.9      44.38          3.47         5.78
ERROR       21    677.1       32.2
TOTAL       23   3539.0
                                   INDIVIDUAL 95 PCT CI'S FOR MEAN
                                   BASED ON POOLED STDEV
LEVEL        N     MEAN      STDEV  ----+---------+---------+---------+-
UDC25        8    15.00       4.93        (---•---)
PDC25       10    35.53       7.29                          (---•--)
CDC25        6    11.58       2.38    (----•---)
                                    ----+---------+---------+---------+-
POOLED STDEV =    5.68                 10        20        30        40
```

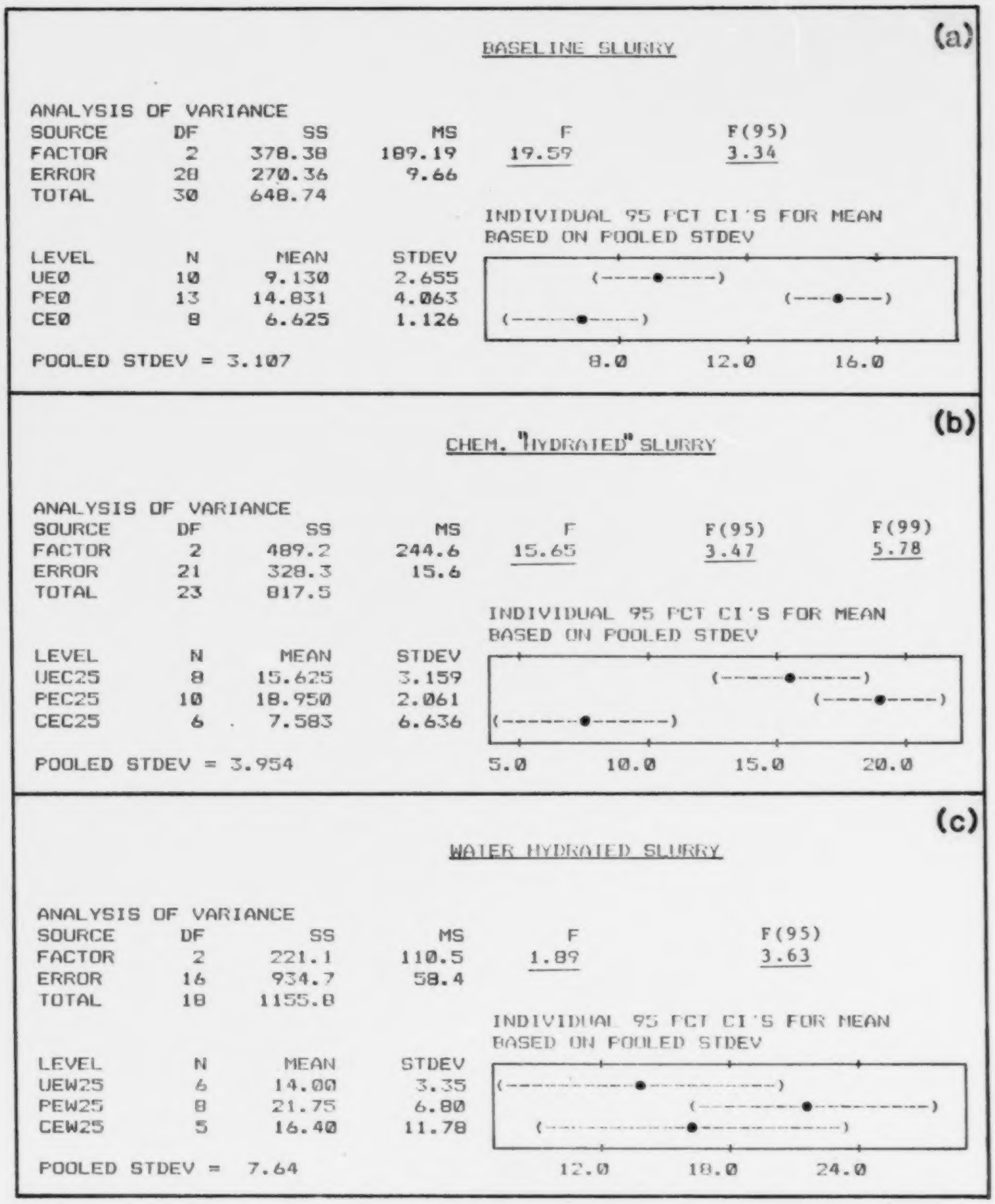
(c)

```
                       WATER HYDRATED SLURRY

ANALYSIS OF VARIANCE
SOURCE      DF       SS         MS          F            F(95)
FACTOR       2      959        480       3.20             3.63
ERROR       16     2395        150
TOTAL       18     3354
                                   INDIVIDUAL 95 PCT CI'S FOR MEAN
                                   BASED ON POOLED STDEV
LEVEL        N     MEAN      STDEV  --+---------+---------+---------+---
UDW25        6    8.667      2.733  (-----------•----------)
PDW25        8   25.125     12.988                   (---------•---------)
CDW25        5   15.200     17.152        (-----------•------------)
                                    --+---------+---------+---------+---
POOLED STDEV = 1E+01                  0        10        20        30
```

Figure 18: Results of one-way analysis of variance on all yield point data for three slurry cases.

PLASTIC VISCOSITY TESTS



(a)

```
                                 BASELINE SLURRY

ANALYSIS OF VARIANCE
SOURCE      DF       SS        MS         F              F(95)
FACTOR       2   378.38    189.19     19.59               3.34
ERROR       28   270.36      9.66
TOTAL       30   648.74
                                  INDIVIDUAL 95 PCT CI'S FOR MEAN
                                  BASED ON POOLED STDEV
LEVEL        N     MEAN     STDEV  ----------+---------+---------+--
UE0         10    9.130     2.655       (-----*------)
PE0         13   14.831     4.063                      (---*---)
CE0          8    6.625     1.126  (------*-----)
                                   ----------+---------+---------+--
POOLED STDEV = 3.107                        8.0      12.0      16.0
```

(b)

```
                               CHEM. "HYDRATED" SLURRY

ANALYSIS OF VARIANCE
SOURCE      DF       SS        MS         F          F(95)        F(99)
FACTOR       2    489.2     244.6     15.65           3.47         5.78
ERROR       21    328.3      15.6
TOTAL       23    817.5
                                  INDIVIDUAL 95 PCT CI'S FOR MEAN
                                  BASED ON POOLED STDEV
LEVEL        N     MEAN     STDEV  -+---------+---------+---------+--
UEC25        8   15.625     3.159             (-----*------)
PEC25       10   18.950     2.061                    (----*----)
CEC25        6    7.583     6.636  (-------*-------)
                                   -+---------+---------+---------+--
POOLED STDEV = 3.954               5.0      10.0      15.0      20.0
```

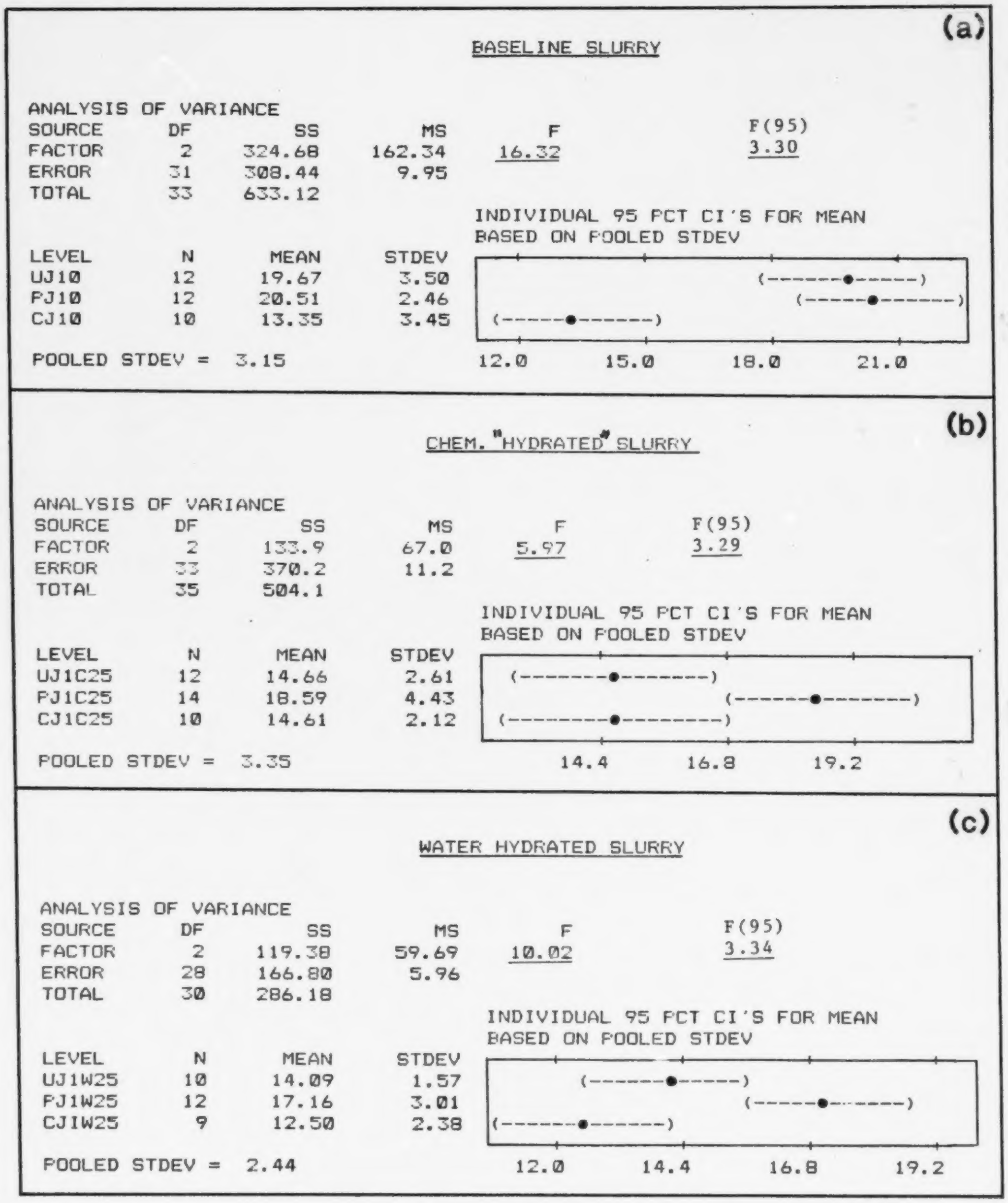
(c)

```
                                 WATER HYDRATED SLURRY

ANALYSIS OF VARIANCE
SOURCE      DF       SS        MS         F              F(95)
FACTOR       2    221.1     110.5      1.89               3.63
ERROR       16    934.7      58.4
TOTAL       18   1155.8
                                  INDIVIDUAL 95 PCT CI'S FOR MEAN
                                  BASED ON POOLED STDEV
LEVEL        N     MEAN     STDEV  ------+---------+---------+-----
UEW25        6    14.00      3.35  (-----------*------------)
PEW25        8    21.75      6.80             (--------*----------)
CEW25        5    16.40     11.78    (------------*------------)
                                   ------+---------+---------+-----
POOLED STDEV =  7.64                   12.0      18.0      24.0
```

Figure 19: Results of one-way analysis of variance on all plastic viscosity data for three slurry cases.

API FILTRATE LOSS TESTS



(a)

```
                                   BASELINE SLURRY

ANALYSIS OF VARIANCE
SOURCE        DF         SS          MS         F                  F(95)
FACTOR         2     324.68      162.34     16.32                  3.30
ERROR         31     308.44        9.95
TOTAL         33     633.12
                                          INDIVIDUAL 95 PCT CI'S FOR MEAN
                                          BASED ON POOLED STDEV
LEVEL          N       MEAN       STDEV   ---------+---------+---------+---------+
UJ10          12      19.67        3.50                         (------*-----)
PJ10          12      20.51        2.46                            (-----*-------)
CJ10          10      13.35        3.45   (-----*-------)
                                          ---------+---------+---------+---------+
POOLED STDEV =   3.15                     12.0      15.0      18.0      21.0
```

(b)

```
                                 CHEM. "HYDRATED" SLURRY

ANALYSIS OF VARIANCE
SOURCE        DF         SS          MS         F           F(95)
FACTOR         2      133.9        67.0      5.97           3.29
ERROR         33      370.2        11.2
TOTAL         35      504.1
                                          INDIVIDUAL 95 PCT CI'S FOR MEAN
                                          BASED ON POOLED STDEV
LEVEL          N       MEAN       STDEV   ---------+---------+---------+---------
UJ1C25        12      14.66        2.61    (--------*--------)
PJ1C25        14      18.59        4.43                    (------*--------)
CJ1C25        10      14.61        2.12   (---------*---------)
                                          ---------+---------+---------+---------
POOLED STDEV =   3.35                            14.4      16.8      19.2
```

(c)

```
                                 WATER HYDRATED SLURRY

ANALYSIS OF VARIANCE
SOURCE        DF         SS          MS         F           F(95)
FACTOR         2     119.38       59.69     10.02           3.34
ERROR         28     166.80        5.96
TOTAL         30     286.18
                                          INDIVIDUAL 95 PCT CI'S FOR MEAN
                                          BASED ON POOLED STDEV
LEVEL          N       MEAN       STDEV   ---------+---------+---------+---------+
UJ1W25        10      14.09        1.57          (------*-----)
PJ1W25        12      17.16        3.01                    (-----*------)
CJIW25         9      12.50        2.38   (------*------)
                                          ---------+---------+---------+---------+
POOLED STDEV =   2.44                            12.0      14.4      16.8      19.2
```

Figure 20: Results of one-way analysis of variance on all API filtrate loss data for three slurry cases.

UNIT API FILTRATE LOSS TESTS

(a)

BASELINE SLURRY

```
ANALYSIS OF VARIANCE
SOURCE      DF        SS        MS        F               F(95)
FACTOR       2     169.4      84.7      3.74              3.29
ERROR       33     747.4      22.6
TOTAL       35     916.7
                                   INDIVIDUAL 95 PCT CI'S FOR MEAN
                                   BASED ON POOLED STDEV
LEVEL       N       MEAN     STDEV +------+---------+---------+---------+-+
UJ30       12      9.167     2.972 |       (---------*--------)           |
PJ30       14      7.064     1.970 | (--------*-------)                   |
CJ30       10     12.450     8.163 |                 (---------*---------)|
                                   +------+---------+---------+---------+-+
POOLED STDEV = 4.759                     6.0       9.0      12.0      15.0
```

(b)

CHEM. "HYDRATED" SLURRY

```
ANALYSIS OF VARIANCE
SOURCE      DF        SS        MS        F           F(95)
FACTOR       2     25.35     12.68      2.40          3.29
ERROR       33    174.14      5.28
TOTAL       35    199.50
                                   INDIVIDUAL 95 PCT CI'S FOR MEAN
                                   BASED ON POOLED STDEV
LEVEL       N       MEAN     STDEV +----------+---------+---------+-------+
UJ3C25     12      6.717     2.195 |        (---------*---------)         |
PJ3C25     14      5.564     1.764 | (--------*--------)                  |
CJ3C25     10      7.620     2.994 |              (---------*----------)  |
                                   +----------+---------+---------+-------+
POOLED STDEV = 2.297                         5.6       7.0       8.4
```

(c)

WATER HYDRATED SLURRY

```
ANALYSIS OF VARIANCE
SOURCE      DF        SS        MS        F           F(95)
FACTOR       2      6.44      3.22      0.94          3.34
ERROR       28     96.22      3.44
TOTAL       30    102.66
                                   INDIVIDUAL 95 PCT CI'S FOR MEAN
                                   BASED ON POOLED STDEV
LEVEL       N       MEAN     STDEV +---------+---------+---------+--------+
UJ3W25     10      6.360     0.692 | (-----------*-----------)            |
PJ3W25     12      6.558     2.054 |    (----------*----------)           |
CJ3W25      9      7.456     2.385 |           (------------*-----------) |
                                   +---------+---------+---------+--------+
POOLED STDEV = 1.854                        6.0       7.0       8.0
```

Figure 21: Results of one-way analysis of variance on all unit filtrate loss data for three slurry cases.

readily accomplished by direct comparison of confidence interval plots for the various tests.

On the basis of direct comparison, the single test which best permits distinction of all three bentonite types is the 10-second gel strength test performed on a 25% acetone chemically "hydrated" slurry (Figure 15b). The apparent viscosity test for the same slurry is almost as good (Figure 17b). This situation is nearly ideal in that both tests are very quick and the performance of both might permit positive identification of an unknown bentonite. To increase the level of confidence even more, the 10-minute gel strength test could also be performed (Figure 16.), and may be necessary in borderline cases to distinguish between unaltered and chemically treated bentonites.

A suggested test protocol for identification of the three bentonite types, therefore, consists of the 10-second gel strength test, the 10-minute gel strength test, and the apparent viscosity test (in any order). The general adequacy of this protocol for use outside of the scope of this study is not known at this time.

HYDRAULIC CONDUCTIVITY

As discussed in Section 4, several different methods used to measure hydraulic conductivity were investigated during the first two phases of this study. In general, conventional methods proved to be too time consuming and typically yielded inconclusive results regarding chemical impact. The reasons are numerous and somewhat interrelated, including: a relatively small number of samples, differences in total pore volume displacement (PVD), and differences in degree of consolidation and hydraulic test gradient between different samples.

For these reasons, an attempt was made to both standardize and expedite hydraulic conductivity testing during the final research phase. The objective of such testing was two-fold: to demonstrate the impact of varying concentrations of acetone on selected unaltered, polymer protected/extended and chemically treated bentonites, and to establish relationships, between selected indicator test parameters and the equilibrium hydraulic conductivity of these bentonites and clays amended by these bentonites (soil-bentonite).

Both objectives were addressed by first applying selected indicator tests to slurries of varying bentonite concentration (3%, 5%, and 7%; weight: volume basis), followed by hydraulic conductivity testing of bentonite filter cakes formed from the same slurries, followed further by hydraulic conductivity testing of a standard clay to which different amounts of bentonite (1%, 3%, 5%; dry weight basis) were added. This approach permitted the generation of indicator test data and corresponding hydraulic conductivity data for different systems containing roughly comparable amounts of bentonite.

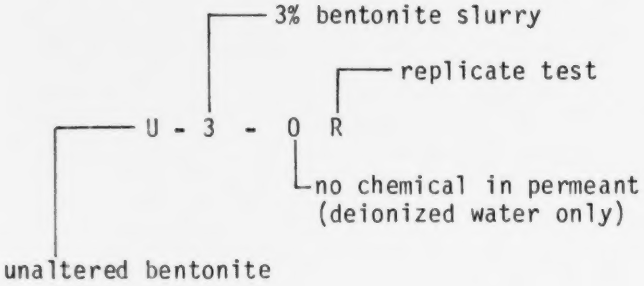
The chosen hydraulic conductivity test procedure involved the exclusive use of API filter press cells converted to serve as miniature rigid wall permeameters (see Section 4 for equipment schematic and justification for use).

Chemical Impact

Filter cakes --

The three bentonites were tested in the form of filter cakes prepared from the various slurries at a driving pressure of 4.0 psi for a time period of thirty minutes (SLP No Ex-03, Appendix D). Samples were then permeated to equilibrium at a head pressure of 2.0 psi (lowest pressure which could be reliably maintained) using deionized water, 25% acetone, and 50% acetone as permeants. Baseline (water as permeant) results were replicated for all samples.

The filter cakes prepared for testing typically were about 0.1 inch (2.5 mm) thick. For this reason, it was possible to achieve a relatively high total pore volume displacement (up to 100) in less than a week. Figures 22a through 22d show test results for the 3& slurry for unaltered bentonite No. 1. Results for the other bentonites and slurry concentrations are presented in a similar format as appended Figures C-1 through C-9. Note that the test number above each plot indicates the bentonite type, slurry concentration, and chemical concentration of the permeant liquid as follows:



A summary plot of equilibrium hydraulic conductivity results for the three concentrations of unaltered bentonite No. 1 as a function of acetone concentration is presented as Figure 23. Comparable results for the polymer protected bentonite (No. 3) and the chemically treated bentonite (No. 6) are presented as Figures 24 and 25, respectively. All baseline tests were replicated and found to be reproducible to within 3.7% on the average (0.2% to 8.2% range; replicate data not shown).

Based upon an error analysis involving the accuracy of driving pressure, permeant outflow measurement, and sample thickness measurement, a worst-case error of ± 20 percent was computed for any individual hydraulic conductivity value (description of analysis presented in Section 6: Quality Assurance). This potential error therefore is applicable to curves for each of the three different bentonite concentrations in Figures 23 through 25. The individual error bands for any two curves overlap in all cases, and it is therefore not possible to clearly distinguish between the three curves on any of the summary figures.

Nevertheless, a measurable and similar effect due to acetone is demon-

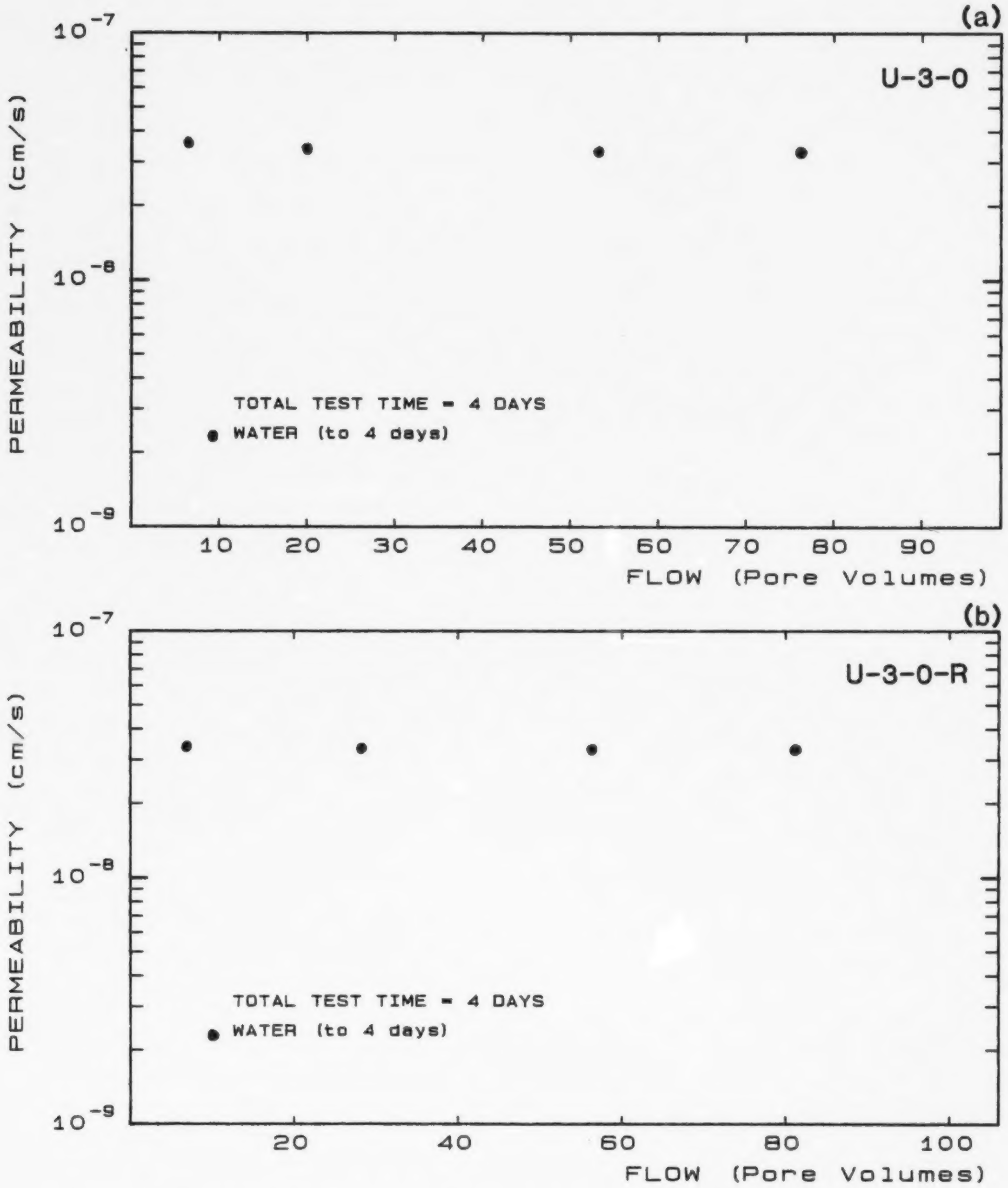
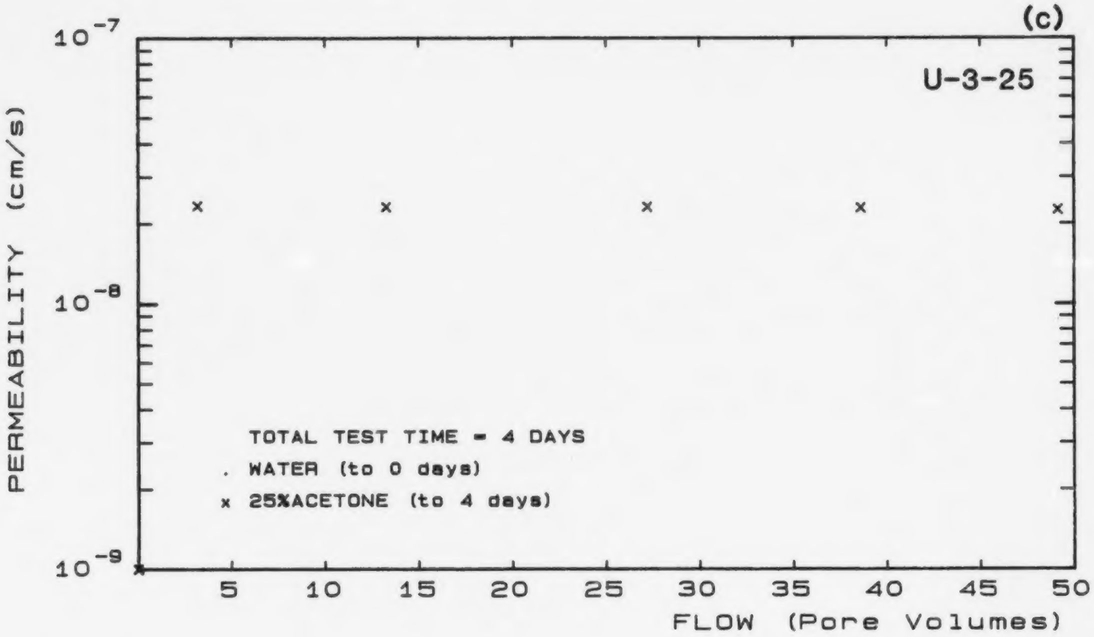


Figure 22 : Hydraulic conductivity of filter cake formed from 3% slurry of unaltered bentonite no. 1.



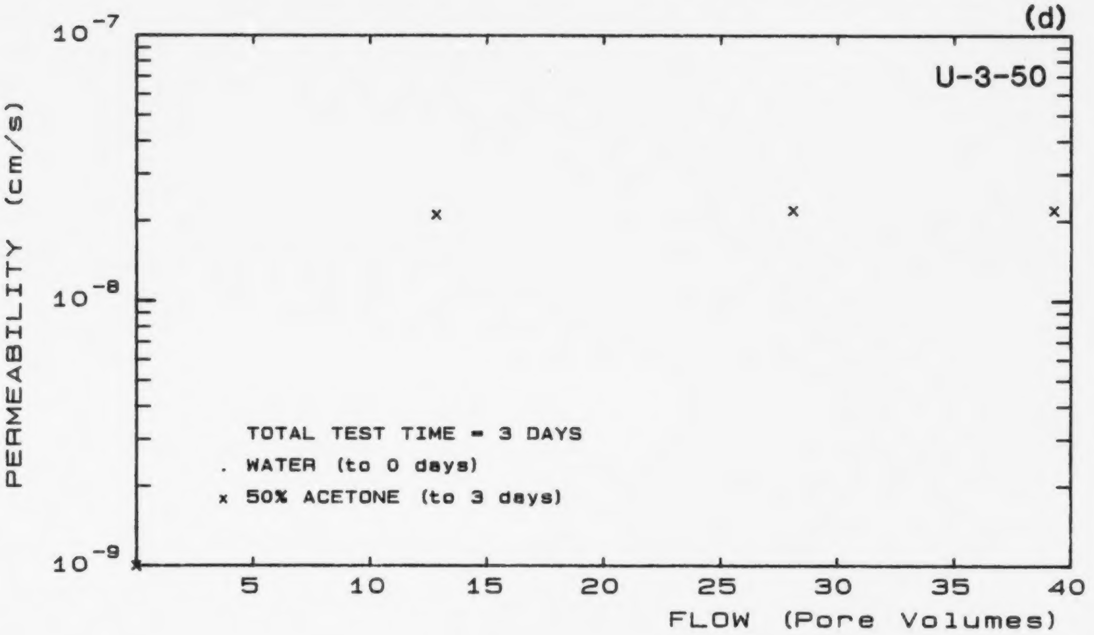


Figure 22 . (continued)

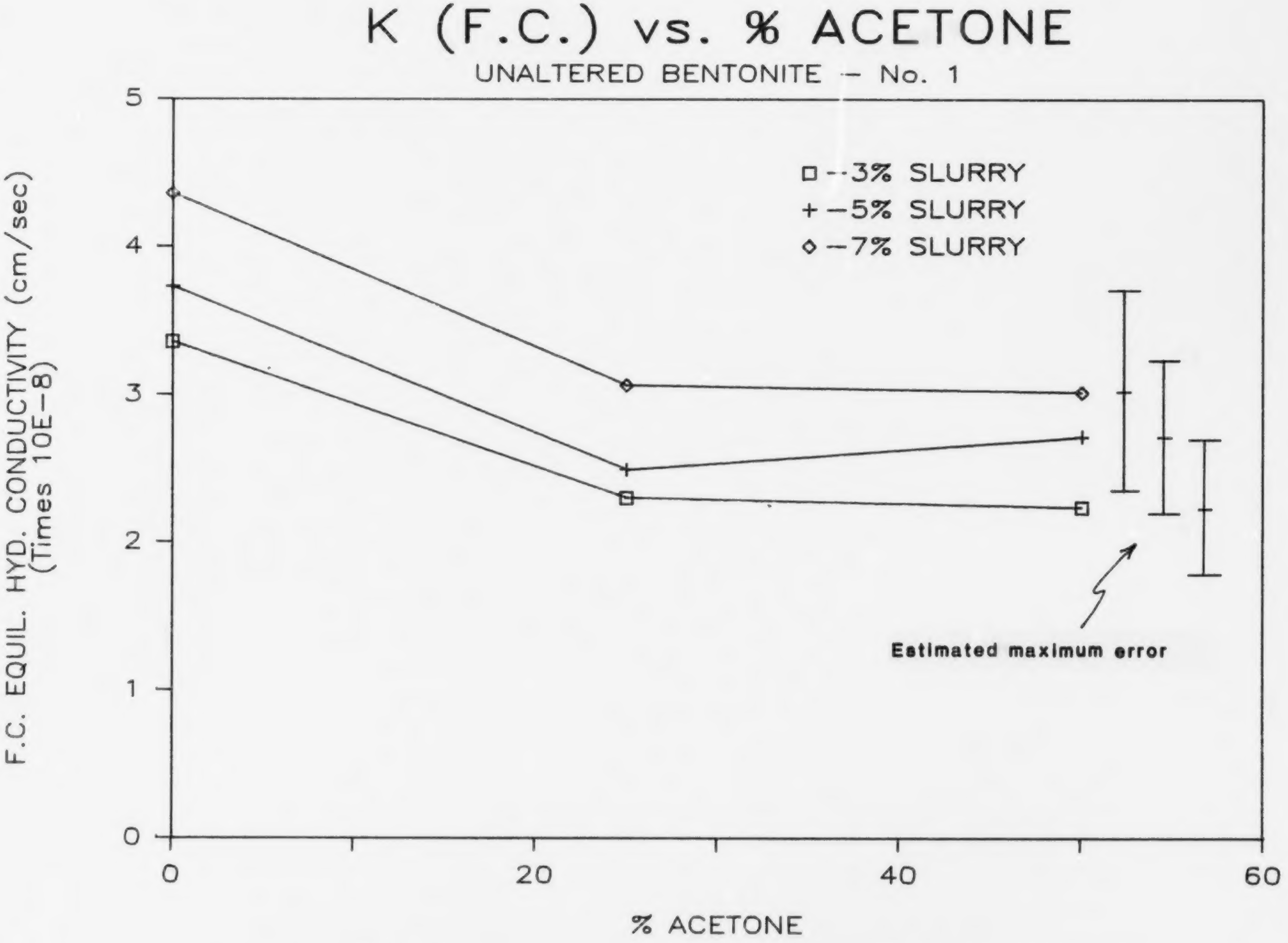


Figure 23: Hydraulic conductivity of bentonite filter cakes permeated by water and various concentrations of acetone

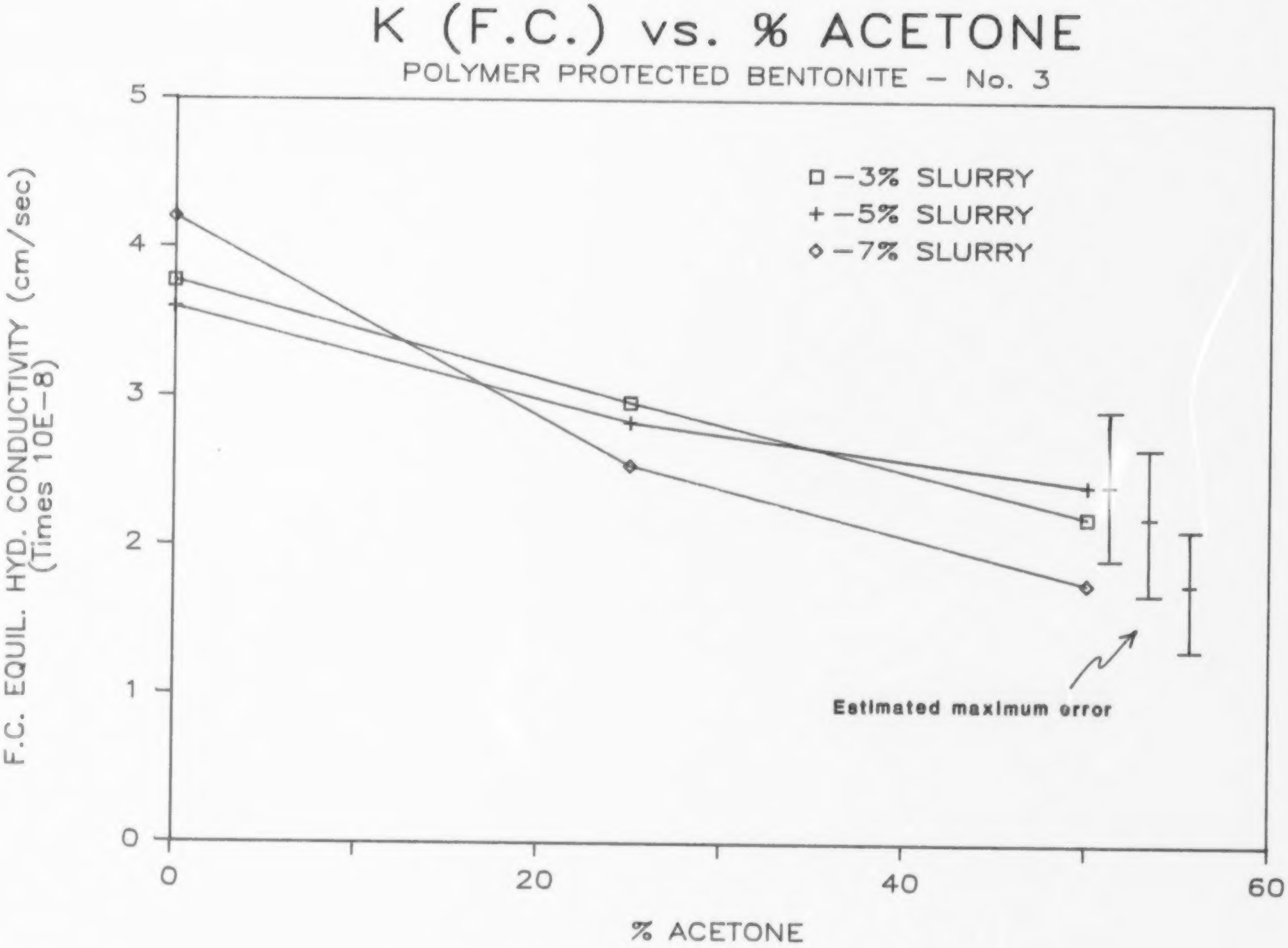


Figure 24: Hydraulic conductivity of bentonite filter cakes permeated by water and various concentrations of acetone

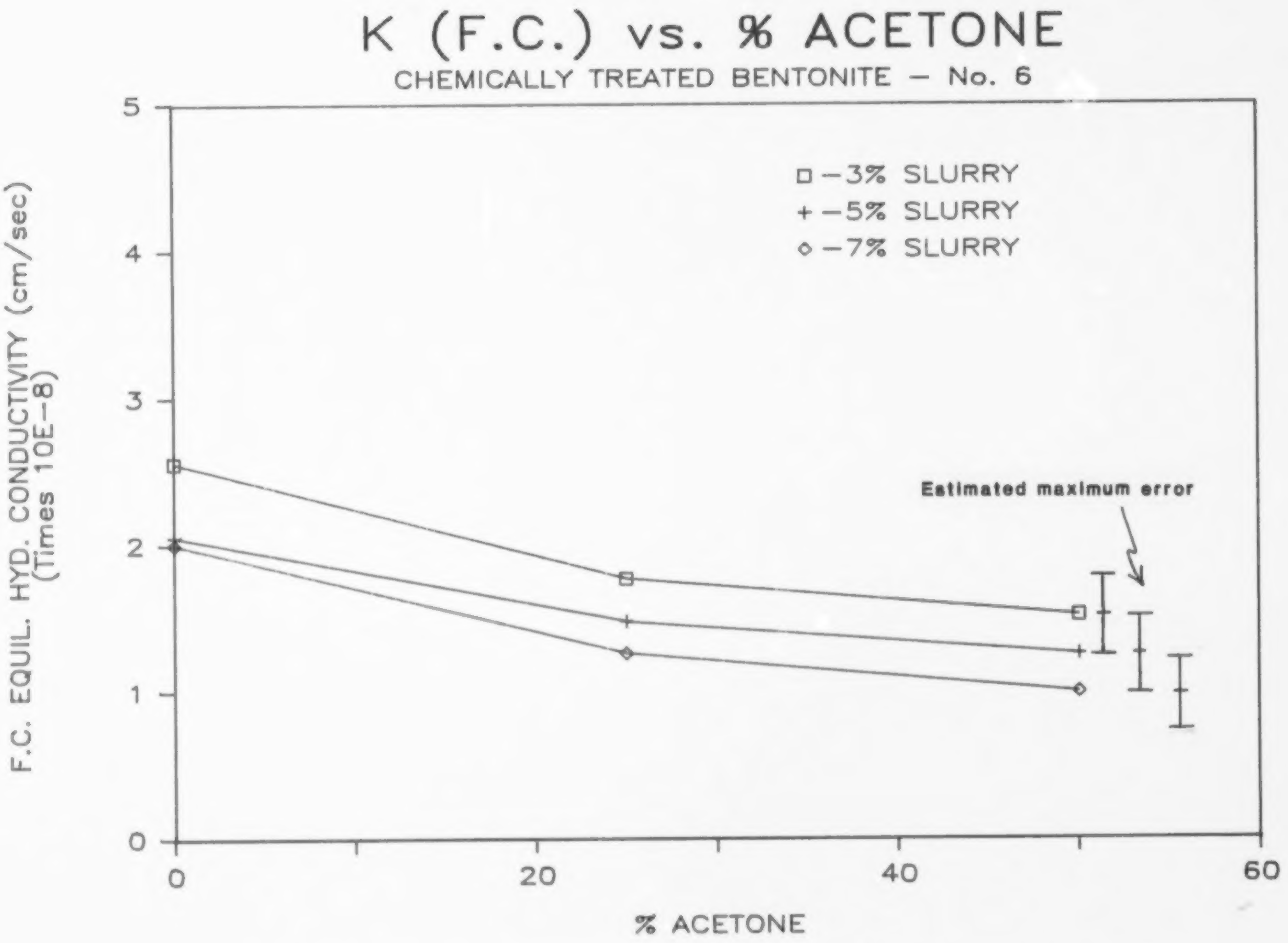


Figure 25: Hydraulic conductivity of bentonite filter cakes permeated by water and various concentrations of acetone

strated for each bentonite. For the three acetone concentrations tested (0%, 25%, 50%, volume basis), there is a nominal decrease in the equilibrium hydraulic conductivity of filter cakes with increasing acetone concentration. In nearly all cases, the greatest amount of reduction is between baseline results and those for an acetone concentration of 25%. For the polymer protected and chemically treated bentonites, a slight additional reduction is observed in the 50% acetone case. These observations suggest the following general conclusion:

- Within the range of concentrations tested, acetone serves to reduce the equilibrium hydraulic conductivity of typical bentonite filter cakes (those formed from slurries ranging from 3% to 7% bentonite and produced under formation pressures comparable to a depth of about 9 feet in a slurry trench), but generally not by more than about 0.1 order of magnitude. However, it should be pointed out that while permeability decreased slightly with increasing acetone concentrations, the trend may change with higher concentrations of acetone.

Despite the fact that curves of different bentonite concentration cannot be distinguished from one another (overlapping error bands), the data also demonstrate that:

- For bentonite slurries used in typical environmental engineering applications such as slurry walls, there is little, if any, measurable difference in the equilibrium hydraulic conductivity of filter cakes (formed under moderate hydraulic pressure) as a function of bentonite concentration of the slurry.

- The equilibrium hydraulic conductivity of a filter cake derived under normal conditions from the chemically treated bentonite may be less than those for the other two bentonite types, but not by more than about 0.2 order of magnitude.

Soil-Bentonites --

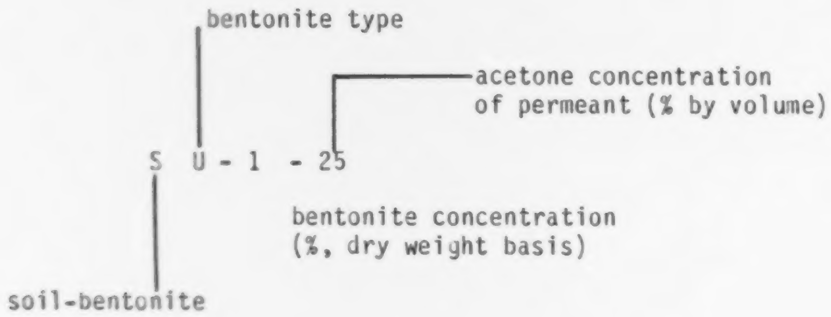
The same three bentonites tested in filter cake form were also tested in soil-bentonite form at bentonite concentrations of 1, 3, and 5 percent (dry weight basis). These concentrations were judged to be more representative of typical-soil bentonites than the higher range used for filter cakes. Also, the maximum concentration of acetone used as a permeant liquid was greater than that used in filter cake tests (75% vs. 50%).

The base soil for soil-bentonite samples was the "Center Hill No. 2" standard soil developed for use in several research projects. This soil contains about 24% silt and clay (minus #200 sieve size) in a matrix of well-graded fine to coarse sand.

Soil-bentonite samples were tested in modified API cells which incorporated a thin sidewall film of bentonite paste to minimize sidewall leakage

(Figure 2a). Samples were consolidated at 5.0 psi for three days, and then permeated to equilibrium at a head pressure of 4.0 psi (SLP No. EX-04, Appendix D). Due to minor variations in sample thickness after consolidation, test gradients generally ranged from 50 to 62. Little, if any, "gradient consolidation" occurred during permeation, however, since all samples were preconsolidated at a greater effective stress than was applied by the hydraulic gradient.

Results for the 1% concentration of unaltered bentonite No. 1 are presented in Figure 26. These same data are appended along with the results for the other bentonite concentrations and types as figures C-10 through C-18. Note that the data are plotted on a semi-log scale and that the identification of test parameters is as follows:


bentonite type
acetone concentration of permeant (% by volume)
S U - 1 - 25
bentonite concentration (%, dry weight basis)
soil-bentonite

Several factors not encountered in filter cake testing are relevant in the case of soil-bentonites. For example, due to a greater sample thickness (factor of 20 or more), testing time was much longer, ranging from nine to thirty-two days and typically more than 14 days. The extended testing time precluded the completion of a few tests which were planned. In order to maximize the utility of results, replication of baseline tests was discontinued mid-way into the program in favor of other primary tests using acetone. Only five of nine planned replications were completed. Furthermore, total pore volume displacement, even with extended test time, was much less for soil-bentonites than for filter cakes, ranging from less than 0.1 (high bentonite and acetone concentrations) to about 25 (low bentonite concentration for one baseline test).

Finally, an estimated maximum error of ± 5 percent was computed for all soil-bentonite hydraulic conductivity data based upon an estimated "worst-case" accuracy in the measurement of pressure and volumetric outflow. The improvement in accuracy relative to filter cake data (± 20%) is due to the grater thickness of soil bentonite samples and the relative insignificance of small errors in the measurement of this parameter.

The results for all soil-bentonite tests are summarized in Figure 27. The data are presented in summary form in order to facilitate direct comparison of type-performance and bentonite concentration effects at various permeant liquid concentrations. Note that the ± 5 percent error margin is repre-

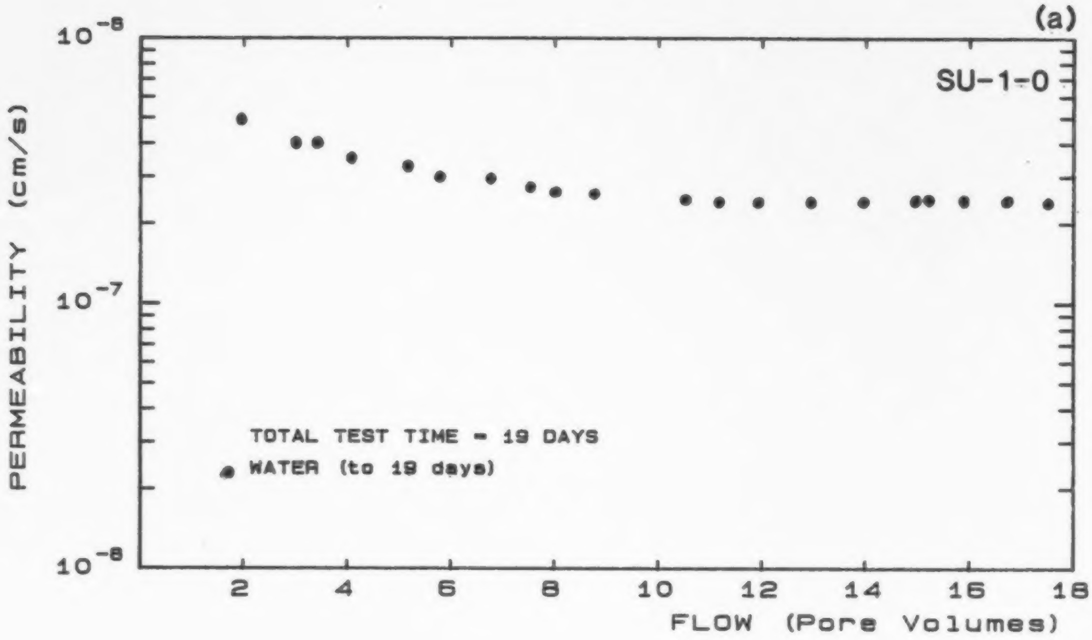


Figure 26. Hydraulic conductivity of soil-bentonite using 1% unaltered bentonite no. 1.

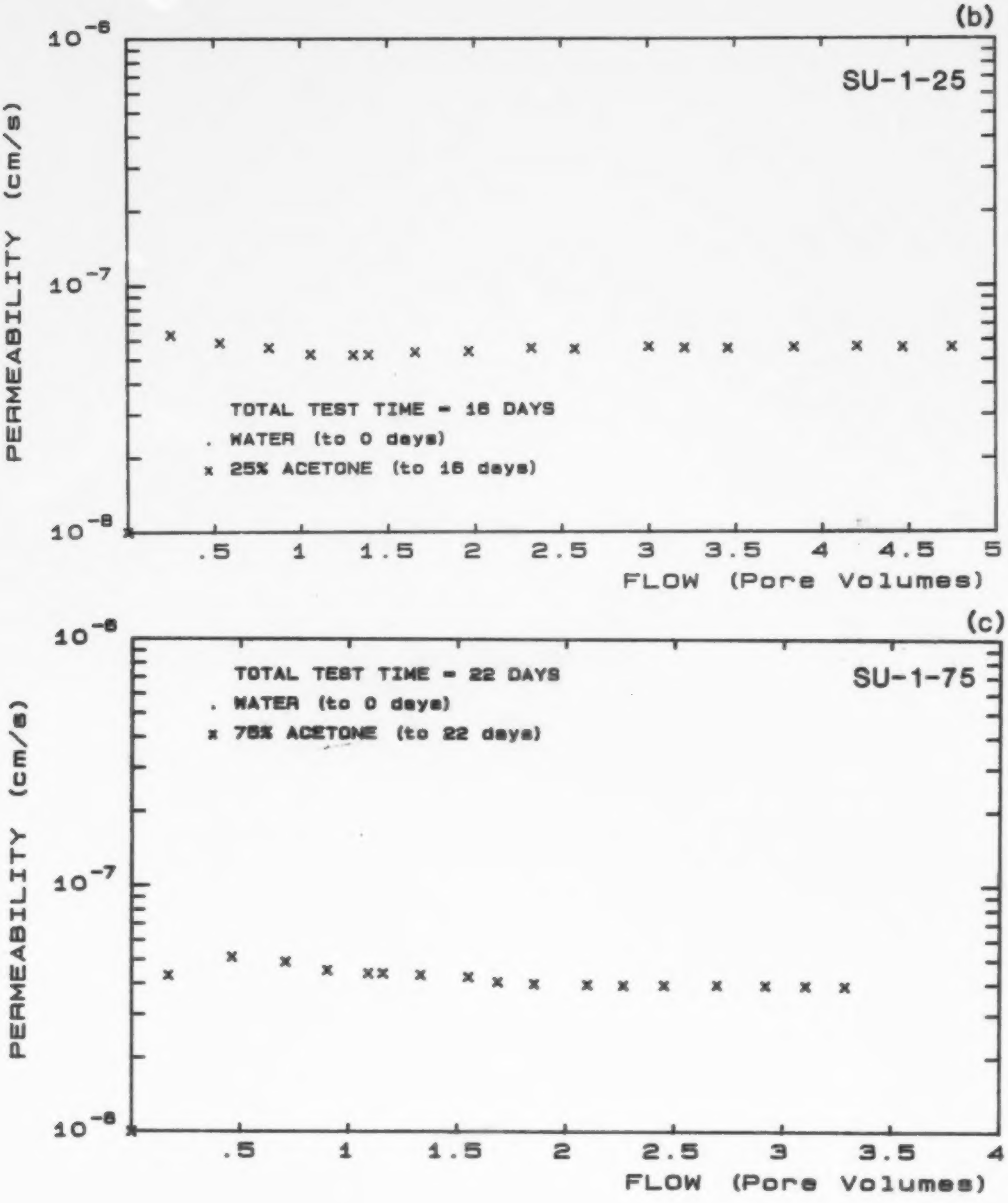


Figure 26: (continued)

sented by the size of the data symbols. The data permit the following general observations:

1. In all cases, 25% acetone as the permeant liquid has the effect of decreasing hydraulic conductivity relative to baseline (0% acetone) values.

2. In all but one case, 75% acetone as the permeant liquid either has no additional effect, or further decreases hydraulic conductivity relative to the 25% acetone case (two cases of "no effect" due to overlapping error bands).

3. Except for the sample made with 3% unaltered bentonite, the data for 75% acetone concentration apparently disagree with those of Brown, et. al. (1984), in that, their tests showed increases in hydraulic conductivity once the concentrations reached or exceeded 75% acetone. Notable differences between these tests and those reported herein, however, include the condition of the samples (compacted vs. non-compacted herein), degree of saturation, and the mineralogy of the samples (micaceous soil used predominantly; limited number of tests performed on a bentonite-sand mixture similar to those tested herein).

4. There is no overall performance distinction which can be made on the basis of bentonite type for any permeant liquid case. For example, although the polymer protected bentonite has the lowest hydraulic conductivity at two of the three bentonite concentrations, it also exhibits the greatest range of the three bentonite types.

5. Considering only the data for the 3% and 5% bentonite concentrations, the polymer protected soil-bentonite has the least hydraulic conductivity, followed by the chemically treated and unaltered bentonite types (maximum difference of up to 1 order of magnitude relative to unaltered bentonite regardless of the permeant liquid).

6. A general trend is observed on the basis of bentonite concentration regardless of permeant liquid. With few (four out of twenty seven) exceptions, hydraulic conductivity is inversely related to bentonite concentration.

The first two observations are in general agreement with previous results reported for filter cakes. The third and fourth observations suggest that there is no significant difference in hydraulic conductivity due to bentonite type. Considering the fifth observation, the effect of bentonite concentration may be estimated for any one of the three permeants liquids. The baseline case is probably the most appropriate for two reasons; first, this case has only one anomaly in the otherwise consistent trend of decreasing

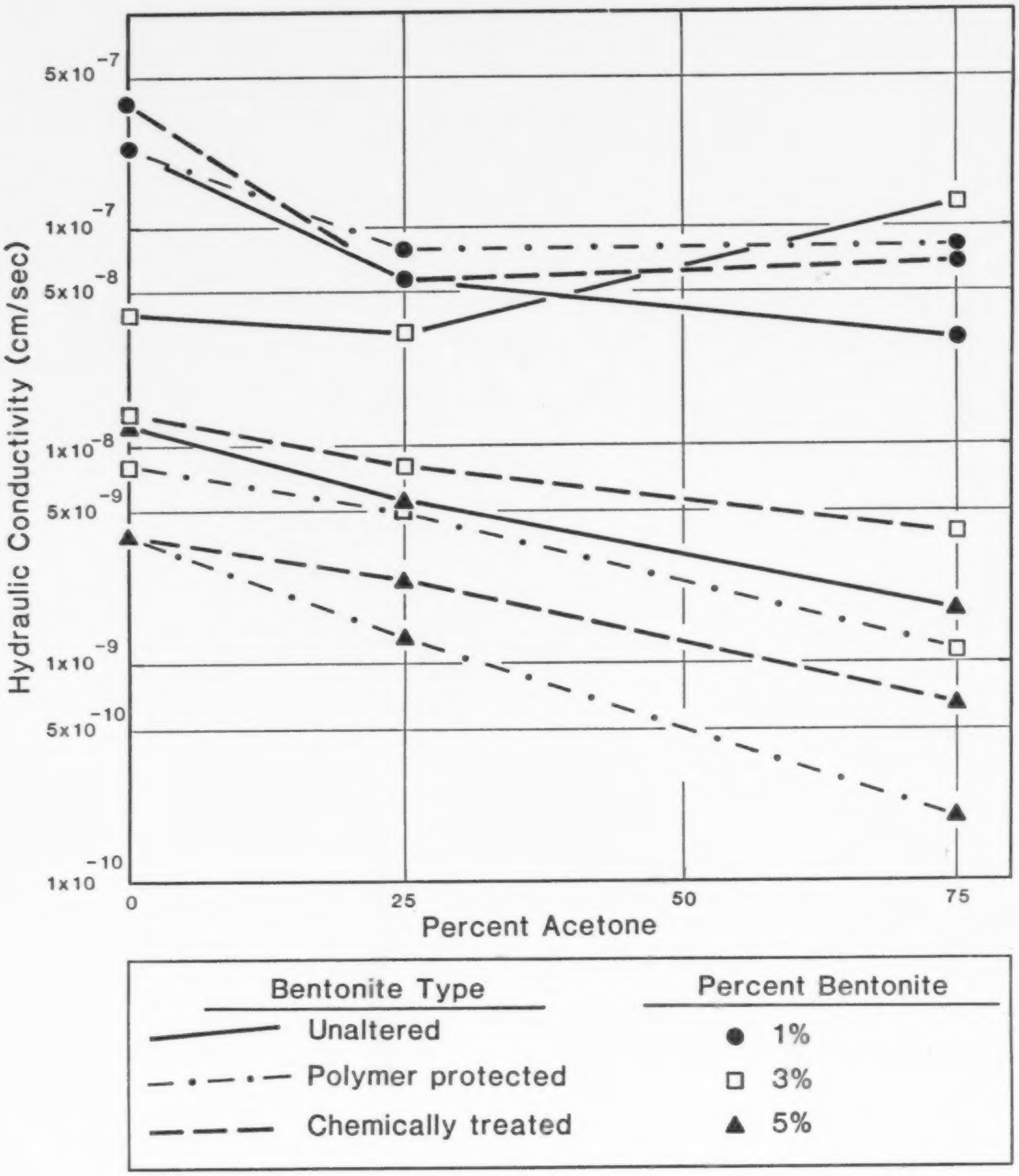


Figure 27: Hydraulic conductivity of soil-bentonite permeated by water and various concentrations of acetone.

hydraulic conductivity with increasing bentonite concentration (3% concentration of polymer protected bentonite), and second, all test replication work was performed for the baseline case.

Table 8 presents the average hydraulic conductivity of all soil-bentonite samples for the baseline case and for each of the three bentonite concentrations. The data suggest that increasing the bentonite concentration of a soil bentonite from 1% to 5% (dry weight basis) decreases the hydraulic conductivity by a factor of more than thirty on the average. The data also suggest an average reduction by a factor of about seventeen for any two percent net increase in bentonite concentration up to a total of five percent.

Table 8 also includes average baseline hydraulic conductivity data for filter cakes formed from slurries having initial bentonite concentrations of 3%, 5% and 7%. One observation reported previously is that the average hydraulic conductivity for the three slurry concentrations is nearly the same (Figure 59). Another pertinent observation is that the hydraulic conductivity of filter cakes is measurably greater than that for soil-bentonites; the amount depending upon the bentonite concentration of the soil-bentonite. Clearly, there exists an optimum bentonite concentration in excess of 5% which would minimize the hydraulic conductivity of this base soil used as a soil-bentonite. The type of bentonite used for this purpose appears to be relatively unimportant.

Indicator Test Correlation

A primary objective of this project was to identify an indicator paramenter which could be used to estimate the impact of acetone on the hydraulic conductivity of pure bentonites and soil-bentonites. The hydraulic conductivity tests on filter cakes and soil-bentonites described in the previous two subsections of this report also served the purpose of indicator test correlation. In all cases, filter cakes and soil-bentonites were exposed to acetone after full water hydration (comparable to water-hydrated slurry case described in connection with general indicator test work).

Filter Cakes --

The most direct correlation should be between indicator tests performed on 3%, 5% and 7% bentonite slurries and hydraulic conductivity tests performed on filter cakes derived from the same slurries. Accordingly, selected indicator test parameters for the three slurry concentrations were measured for each of the three bentonite types prior to filter cake formation and hydraulic conductivity testing. An example of this type of data for a single candidate indicator parameter and bentonite type is shown as Figure 28a. The same data are plotted as a function of filter cake hydraulic conductivity in Figure 28b.

Each "curve" in Figure 28b represents a different slurry concentration for which a standard filter cake was permeated by 0%, 25%, and 50% acetone. For example, the data for the 5% bentonite slurry (solid line) fail to exhibit a consistent trend in 10-minute gel strength with increasing acetone concentration. Since this indicator parameter does not display a consistent

TABLE 8. COMPARATIVE PERFORMANCE OF SOIL-BENTONITES AND FILTER CAKES

	Bentonite Concentration		
SOIL-BENTONITES	1%	3%	5%
Average baseline Hyd. Conductivity, cm/sec (all Types)	2.8×10^{-7}	1.7×10^{-8}	8.2×10^{-9}
Performance Factor relative to 1% concentration	1.0	16.5	34.2

	Slurry (bentonite) Concentration			
FILTER CAKES	-	3%	5%	7%
Average baseline Hyd. Conductivity, cm/sec (all types)		3.2×10^{-8}	3.2×10^{-8}	3.6×10^{-8}
Performance Factor relative to comparable soil-bentonite	-	-1.9	-3.9	-

Note : A negative performance factor indicates a relative increase in hydraulic conductivity.

trend as a function of acetone concentration, it cannot be used to "predict" the consistent trend in hydraulic conductivity observed for the same bentonite in Figure 23. The same is true for the 3% bentonite slurry (dotted line).

The trend exhibited by the data for the 7% bentonite slurry (dashed line), however, is very similar to that shown in Figure 23. In Figure 23, hydraulic conductivity decreases between 0% acetone and 25% acetone with little or no additional decrease thereafter. In Figure 28b, the hydraulic conductivity trend is about the same, but as a function of both acetone concentration and 10-minute gel strength. This similarity also exists for the other two bentonite types (compare Figures 28d and 24; Figures 28f and 25).

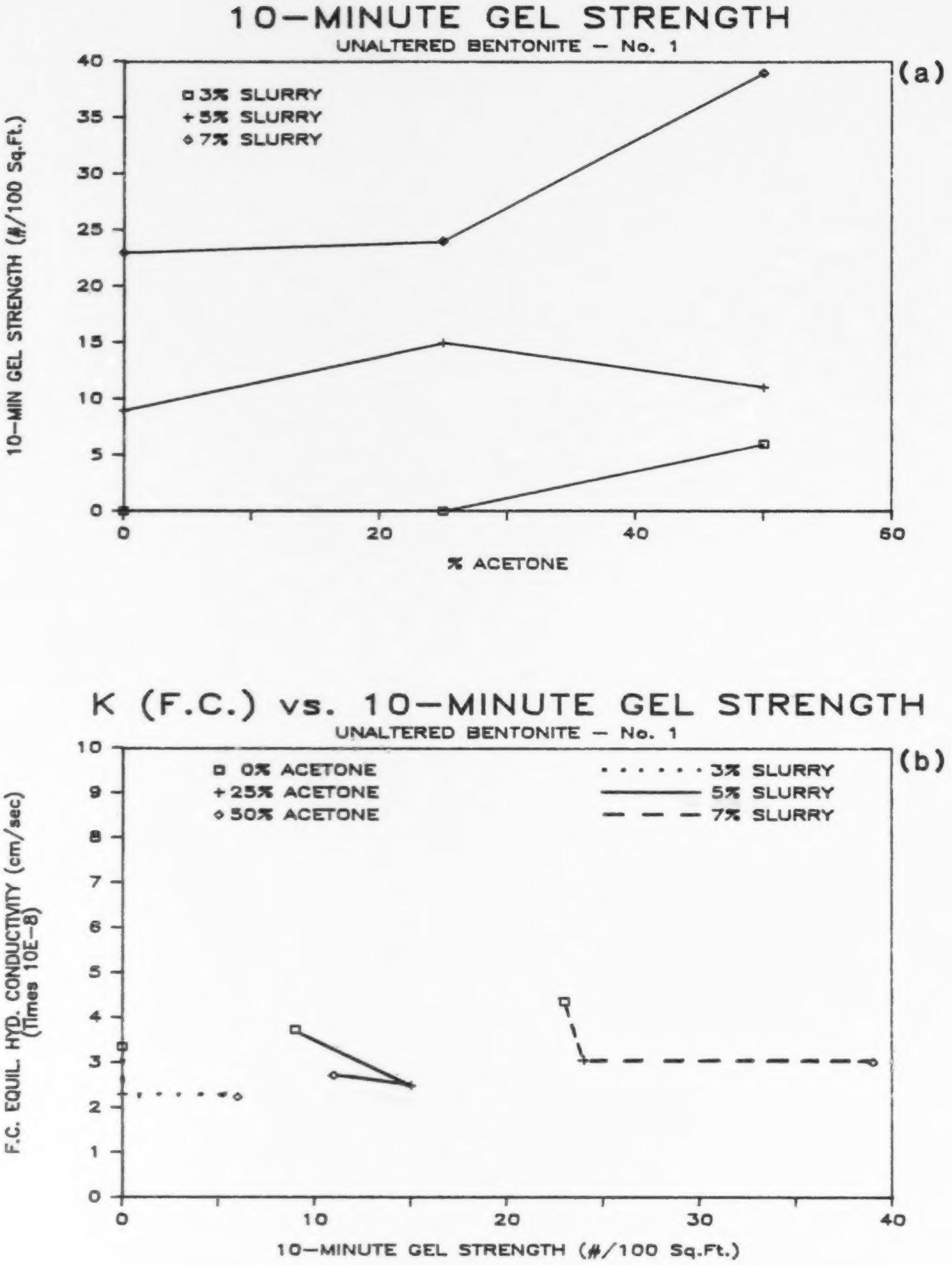
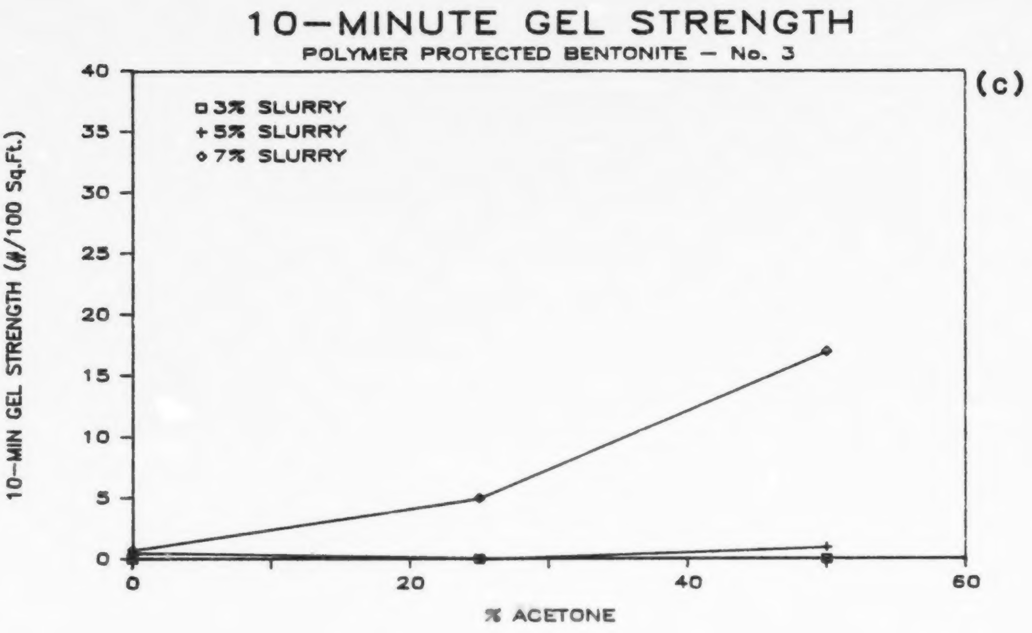


Figure 28 : (a) Phase III 10-Minute Gel Strength test results.
(b) Correlation between indicator parameter and hydraulic conductivities of bentonite filter cakes.



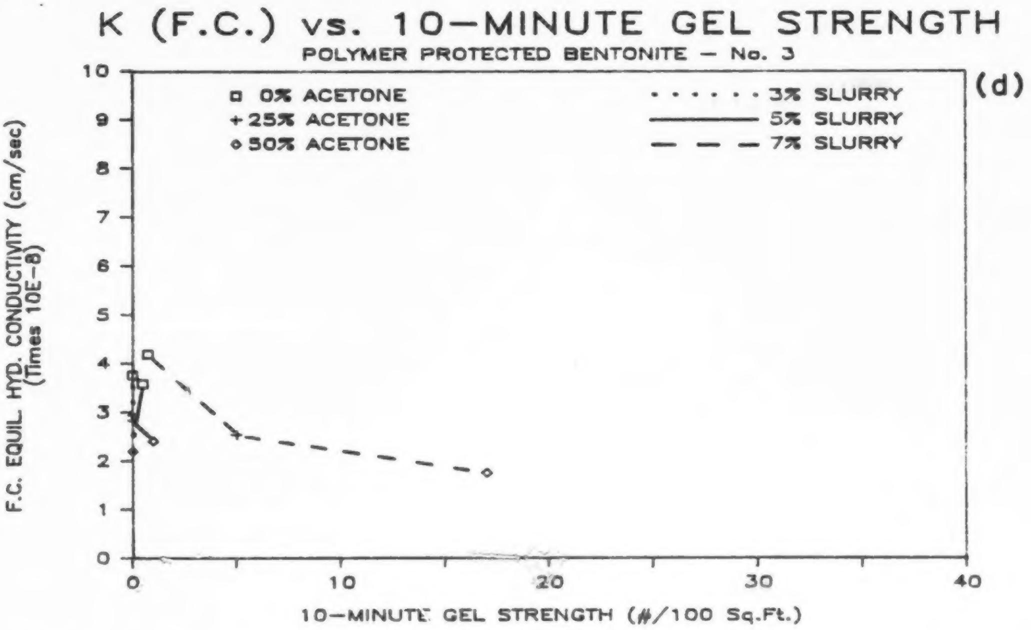
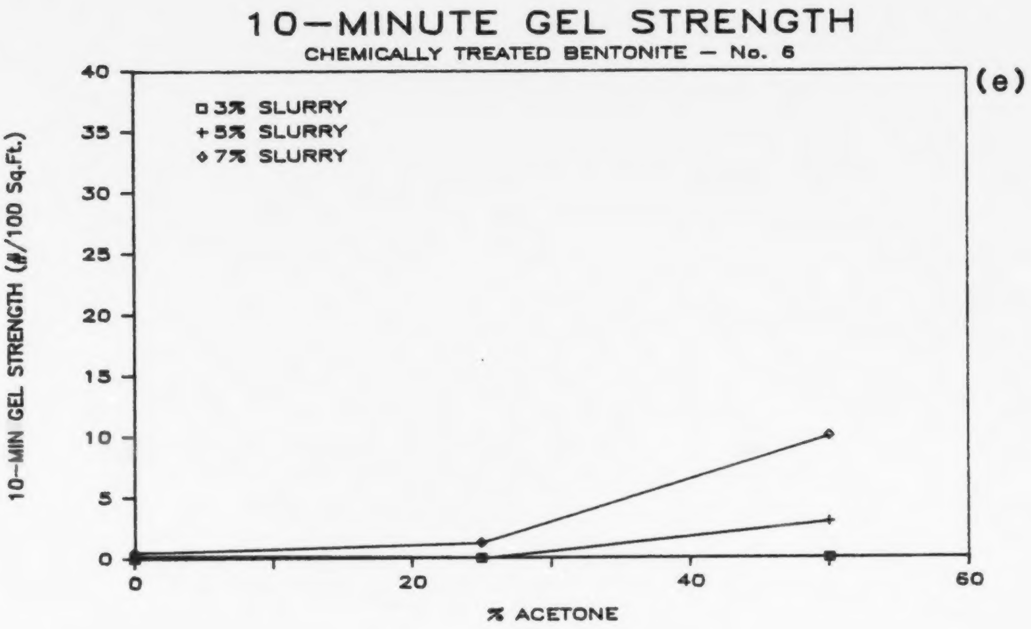


Figure 28 contd.; (c) Phase III 10-Minute Gel Strength test results. (d) Correlation between indicator parameter and hydraulic conductivities of bentonite filter cakes.



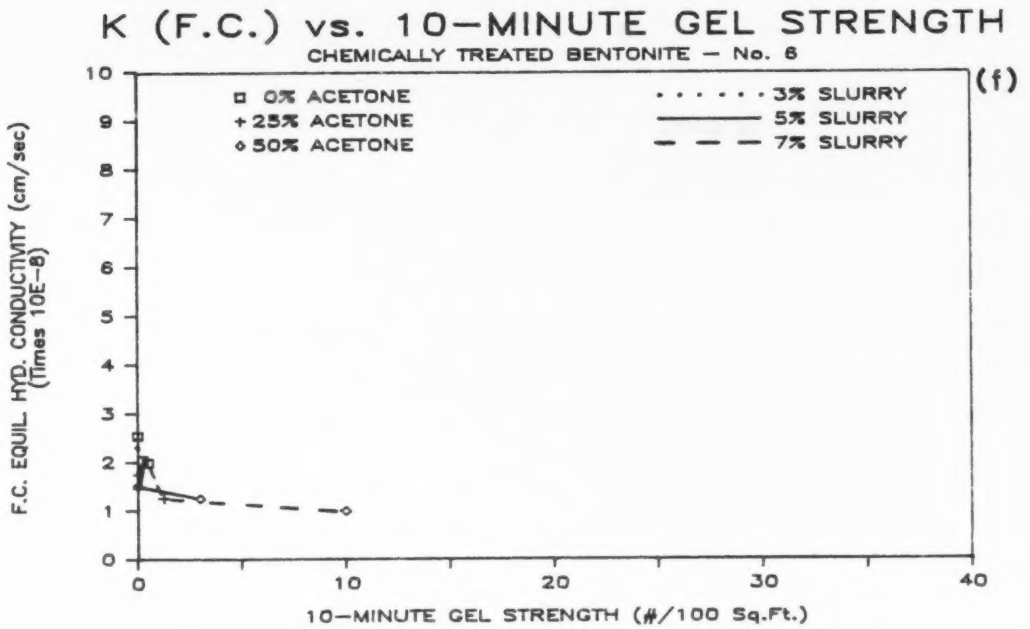


Figure 28 contd.; (e) Phase III 10-Minute Gel Strength test results.
(f) Correlation between indicator parameter and hydraulic conductivities of bentonite filter cakes.

Of all the comparable sets of appended correlation data for the various indicator tests (figures C-19 through C-26), those shown herein for the 10 minute gel strength test appear to exhibit the best overall correlation. Moreover, recall that the 10-minute gel strength test was also identified as one of the three tests in the suggested test protocol for type-distinction. Other tests, such as marsh funnel viscosity appear to be almost as good, while yet other tests fare well for one bentonite type but not for the other two.

Despite the apparent correlation, however, it must be concluded that the 10-minute gel strength test has marginal utility as a predictor of acetone impact on the hydraulic conductivity of filter cakes. The primary basis for this opinion is simply that acetone has very minor effect on the hydraulic conductivity of bentonite filter cakes and, therefore, a predictive capability is relatively unimportant.

Soil-Bentonites --

As demonstrated earlier, the hydraulic conductivity of soil-bentonites is significantly affected by the amount of acetone in the permeant liquids, varying in many cases by nearly an order of magnitude (Figure 27). The method of identifying an indicator parameter that predicts acetone impact on hydraulic conductivity in this case is similar to that described for filter cakes. It is complicated, however, by the fact that different concentrations of acetone were employed in indicator test work on slurries than were used in soil-bentonite hydraulic conductivity testing. Indicator tests were performed on bentonite slurries having acetone concentrations of 0%, 25%, and 50%, whereas soil-bentonite hydraulic conductivity was measured for permeant liquids containing 0%, 25%, and 75% acetone. The only direct bases of comparison, therefore, are the 0% and 25% acetone cases.

Despite this limitation, the search for a predictive indicator is facilitated by using the same principles discussed for the analysis of correlation in the filter cake case, i.e., the indicator parameter should exhibit a uniform trend as a function of acetone concentration since the observed hydraulic conductivity trend for soil-bentonites is generally uniform (Figure 27). Using this criterion, the indicator parameters deemed best for filter cake correlation should also be the most appropriate for soil-bentonite correlation, i.e., data for the 7% bentonite slurries in the 10-minute gel strength test and (perhaps) the marsh funnel viscosity test.

Plots of hydraulic conductivity as a function of 10-minute gel strength for the various bentonite types, soil-bentonite concentrations, and acetone concentrations of 0% and 25% are presented in Figure 29. Comparable plots for the marsh funnel viscosity test are presented in Figure 30.

Neither 10-minute gel strength nor marsh funnel viscosity appear to be good predictors of acetone impact on soil-bentonites. The 3% soil-bentonite "curve" for the 10-minute gel strength test (Figure 29a) appears to indicate

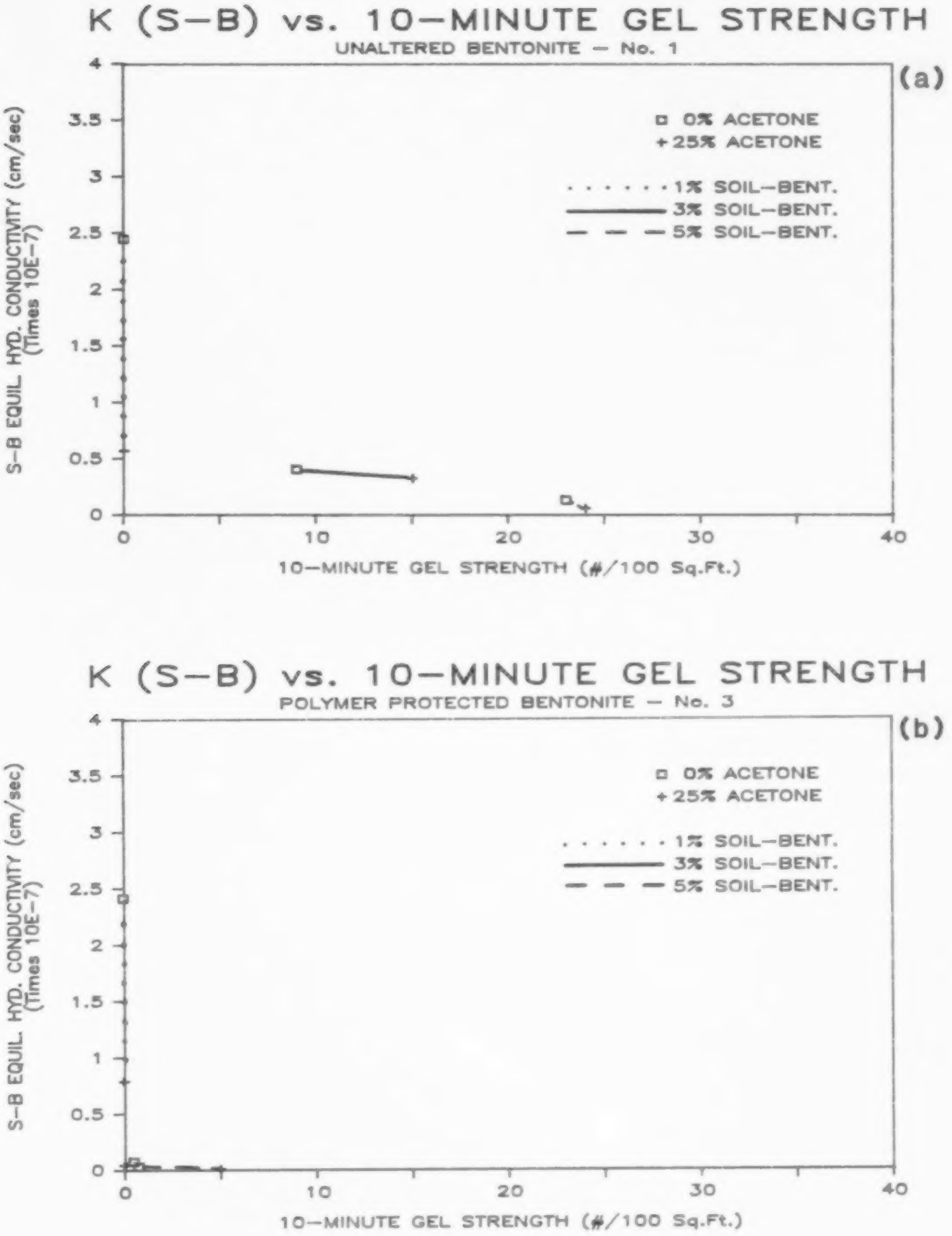


Figure 29: Correlation between indicator parameter and hydraulic conductivities of various soil-bentonites

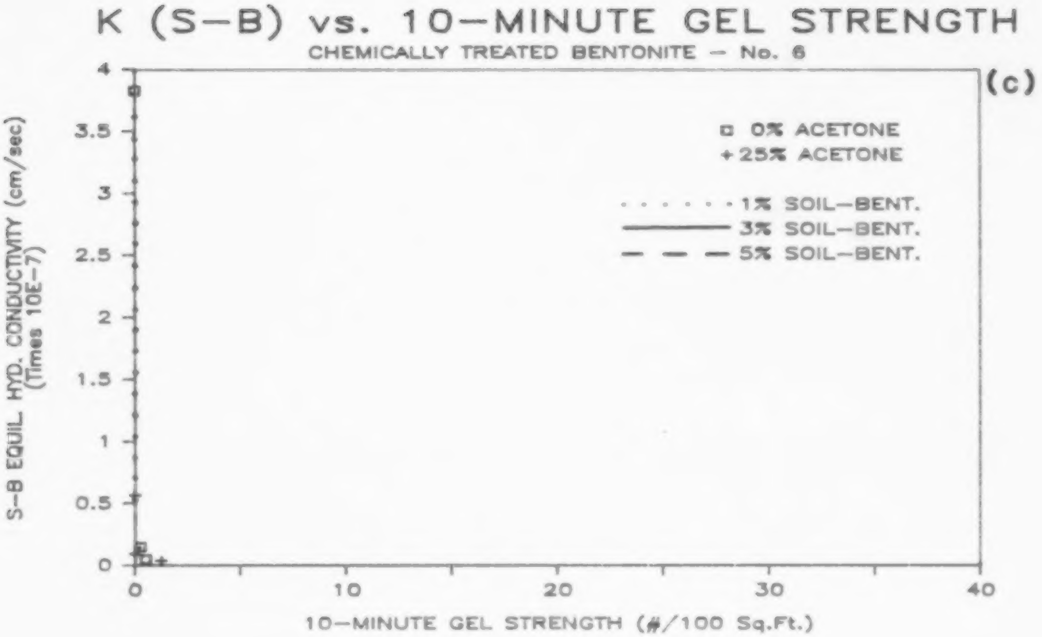


Figure 29: (continued)

decreasing conductivity with increasing gel strength for unaltered bentonite, but not for the other two bentonite types (Figures 29b and c). Other 10-minute gel strength data (1% and 5% soil-bentonites) and those for the marsh funnel viscosity test are not consistent with the observed trend in hydraulic conductivity.

Although with substantial additional testing it might be possible to identify a predictive indicator of acetone impact on the hydraulic conductivity of soil-bentonites, such cannot be demonstrated as a result of the research described herein.

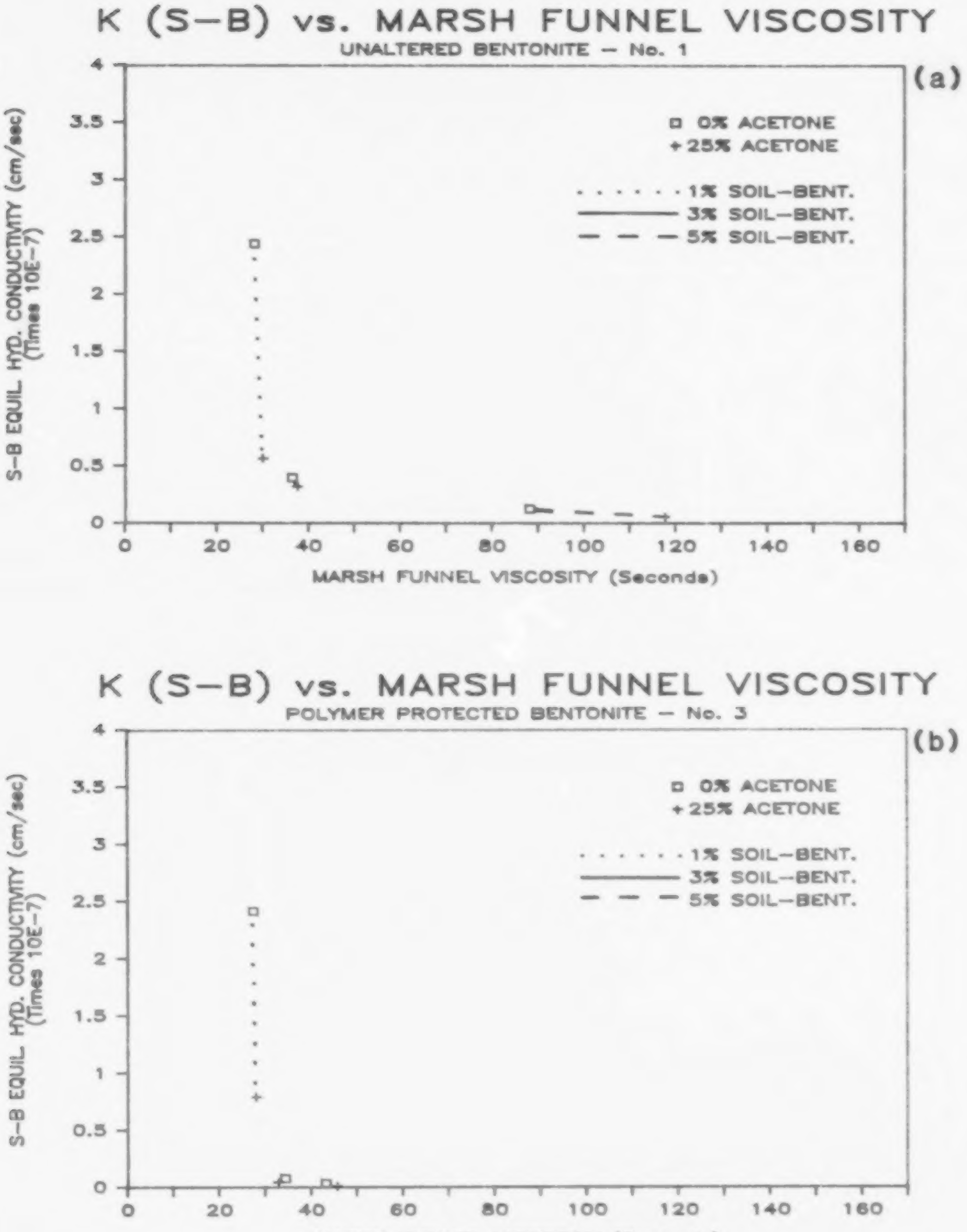


Figure 30: Correlation between indicator parameter and hydraulic conductivities of various soil-bentonites

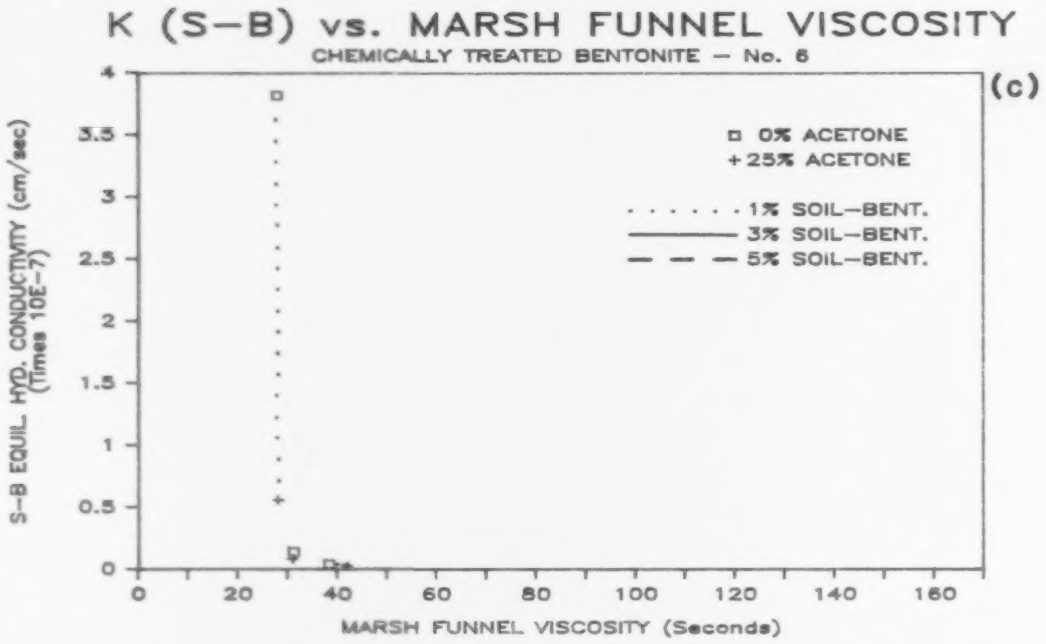


Figure 30: (continued)

SECTION 6

QUALITY ASSURANCE

GENERAL

The research described herein is supported by an approved Quality Assurance Project Plan dated May 2, 1985, and a single addendum thereto. Both documents were reviewed in accordance with the guidelines provided in the "QA Porcedures for HWERL, August 1985", and the "Interim Guidelines and Specifications for Preparing QA Project Plans, QAMS 005/80".

The overall QA objective for this project was to provide data quality at EPA Level 3:

> "Projects intended to evaluate and select basic options or to perform preliminary assessments of unexplored areas require QA levels to produce scientifically but not legally defensible conclusions. The data must be valid in a relative but not necessarily an absolute way and must support the technical choices made."

Five specific considerations that frame the QA effort in general and that were addressed in the above documents are briefly described in the following paragraphs.

Accuracy

Civil engineering research activities often involve measurement of various test parameters on construction materials whose composition and properties are well known or established within specific limits (steel, concrete, etc.). Such is not the case in the study of earth materials and their response under various environmental conditions. Results from standard geotechnical tests may vary widely, even when the soil appears to be uniform. As such, there exist no scientific standards or true values against which one could estimate accuracy of the various indicator test and hydraulic conductivity measurements performed during this study.

Precision

No specific industry precision criteria for the various test parameters exist. Throughout the study, precision considerations were addressed in terms of limited replication of selected test procedures judged to be either most promising in terms of the stated research objective, or most likely to exhibit the greatest degree of variability. Routine test replication was conducted on about 24 percent of all tests performed during the three phases of this study. Specific information regarding the precision of indicator tests and hydraulic conductivity tests is presented in following subsections.

Completeness, Representativeness, Comparability

These three considerations generally address the validity of research results on a limited sampling of a population in terms of applicability to the population as a whole. Due to the necessarily limited scope of the research described herein, it cannot be said that the three general bentonite type classifications (unaltered, ploymer protected/extended, chemically treated) have been fully characterized, nor can it be stated that no other legitimate classifications exist within the population of commercial bentonite products. Therefore the completeness, representativeness, and comparability of results reported herein are not known. Based upon results, however, it does appear that the three types are measurably different and that additional work to determine the level of completeness, representativeness and comparability may be warranted.

An on-site Quality Assurance Technical Systems Audit was performed at the Center Hill Facility on May 1 and 2, 1985. Recommendations pertaining to this project are summarized as follows:

- Where possible, test equipment should be modified to permit direct data recording onto hard copy in order to minimize subjectivity of observations.
- All results should be recorded in ink and all test forms should be initialed by the analyst conducting the test.
- Samples stored in the moisture room should be identified with water-resistant labels.
- The inherent precision of the data should be reflected in terms of the reporting of significant figures.

As reported in Section 4, it was not possible to automate the rotational viscometer due to various mechanical and vendor-related problems; otherwise, the above items were addressed.

The primary elements of the approved QAPP that define the framework within which all testing was performed are as follows:

- Specific data forms for each indicator test and summary data forms for compilation of results and general project status tracking
- Sample preparation, custody and disposition log
- Sample labeling format keyed specifically to identify bentonite, chemical, and indicator test

- Instrument calibration log
- Analyst proficiency log
- Corrective action log
- Development and mandatory use of Standard Laboratory

Procedures (SLP) for sample preparation and testing

INDICATOR TESTS

Specific QA considerations for indicator test work are discussed in Section 5 under the heading "Sources of Error". As reported in Section 5, ther precision of meaurement of the properties of a standard reference slurry of one selected bentonite differed between the various indicator tests. The coefficient of variation (CV) for all trials ranged from 0.0 to 26.0 (Table 5). Despite relative differences in precision for different tests, it was assumed that operator and batching variability would not mask bentonite type variability thereby precluding type-distinction. Such was subsequently demonstrated in Section 5 under the heading of "Type Distinction" using a one-way analysis of variance of all data for selected indicator tests and bentonite types.

HYDRAULIC CONDUCTIVITY TESTS

Hydraulic conductivity tests described in Section 5 of this report involved the measurement of five primary parameters:

- H; permeant driving pressure, psi
- Q; permeant outflow, ml (cm^3)
- L; sample thickness, mm
- A; sample cross-sectional area, cm^2
- T; elapsed permeation time, sec.

Using these parameters, hydraulic conductivity was computed as:

$$k \text{ cm/sec} = \frac{(Q)(L)(0.1)}{(H)(70.28)(A)(T)}$$

Where, the constant 0.1 is used to convert thickness to units of centimeters, and 70.28 is used to convert pressure in psi to centimeters of water head.

Sample thickness and area were measured with a standard vernier caliper accurate to 0.05 mm + 0.025. Individual time measurements were recorded to the nearest whole minute (60 seconds) over a total test time ranging from three to more than thirty days. The major potential sources of measurement error during the test were driving pressure (H) and permeant outflow (Q).

Test pressure was regulated using a Fairchild model 10 precision air regulator rated for use over a range of 0.5 to 30.0 psi, and having a sensitivity of 0.0045 psi. Based upon the accuracy of the dial guage attached to the regulator, however, it was possible to measure pressure with an accuracy of only ± 0.1 psi.

Outflow was collected in graduated cylinders and measured by direct observation. The worst-case accuracy of such measurement is estimated to be 0.5 ml ± 0.25.

Using the above worst-case estimates of pressure and outflow measurements, it was possible to comput a maximum potential error assuming that errors associated with the measurement of time and sample dimensions were insignificant. Using this approach for extreme cases (samples having the smallest total outflow vs. samples having the largest total outflow, for example) it was determined that the maximum error in the measurement of hydraulic conductivity of soil-bentonite samples was ± 5 percent.

In the case of bentonite filter cake samples, the assumption of insignificant error in the measurement of sample thickness wasnot reasonable. A worst-case total error for these samples was estimated based upon precision of pressure and outflow measurements as well as measurement of thicknesses for a filter cake less than 1.0 mm thick. The maximum error computed for the worst-case combination of variables measured to compute hydraulic conductivity of bentonite filter cakes was ± 20 percent.

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APPENDIX A

PRIMARY TEST RESULTS

Raw Data; Tables A-1 through A-24

Raw Data; Figures A-1 through A-8

Statistical Parameters;

Tables A-25 through A-35

TABLE A-1. PRIMARY INDICATOR TEST RESULTS (Phase I)

Type: UNALTERED	CHEMICALLY 'HYDRATED' Slurry						
Bentonite Id: 1	% ACETONE IN DEIONIZED WATER						
INDICATOR TEST	0 (BASELINE Slurry)	R_1	R_2	25	R1	75	R_1
A. MARSH FUNNEL VISCOSITY (sec)	31.6	-	-	70.0	-	26.2	-
B. GEL STRENGTH (lb/100 ft^2) - 10 sec	3.5	-	-	18.0	-	2.5	-
C. APPARENT VISCOSITY (cP)	9.5	-	-	16.0	-	3.0	-
D. YIELD POINT (lb/100 ft^2)	7.0	-	-	20.0	-	3.0	-
E. PLASTIC VISCOSITY (cP)	6.0	-	-	12.0	-	1.5	-
F. API FILTRATE LOSS (ml)	23.7	-	-	17.4	-	13.2	-
cake thickness [mm]	[3.0]	-	-	[3.0]	-	[2.5]	-
(ml/mm)	7.9	-	-	5.8	-	5.3	-
G. FREE SWELL (24-hr)	38	-	-	52	-	14	-
H. pH (initial/24-hr)	9.4/9.0	-	-	9.1/9.2	-	9.5/9.5	-
J. % RETAINED, #200 Sieve	1.9	-	-	0.9	-	0.6	-
K. TURBIDITY (NTU)	848	-	-	1064	-	700	-
L. CRACKING PATTERN	U	-	-	SF	-	HF	-
M. LIQUID LIMIT (%)	560	650	630	1058	-	407	-

NOTE: -Key for cracking pattern test results: U (uniform), f (flocculated), C (cracked), P (pinholes), S (slight), and H (heavy)
-all slurries remixed immediately prior to testing

TABLE A-2. PRIMARY INDICATOR TEST RESULTS (Phase I)

Type: UNALTERED	CHEMICALLY 'HYDRATED' Slurry						
Bentonite Id: 2	% ACETONE IN DEIONIZED WATER						
INDICATOR TEST	0 (BASELINE Slurry)	R_1	R_2	25	R1	75	R_1
A. MARSH FUNNEL VISCOSITY (sec)	38.2	-	-	42.9	-	27.3	-
B. GEL STRENGTH (lb/100 ft^2) - 10 sec	3.0	-	-	6.0	-	3.0	-
C. APPARENT VISCOSITY (cP)	13.5	-	-	20.0	-	3.75	-
D. YIELD POINT (lb/100 ft^2)	8.0	-	-	12.0	-	1.5	-
E. PLASTIC VISCOSITY (cP)	9.5	-	-	14.0	-	3.0	-
F. API FILTRATE LOSS (ml)	16.4	-	-	12.8	-	31.7	-
cake thickness [mm]	[1.0]	-	-	[1.0]	-	[1.0]	-
(ml/mm)	16.4	-	-	12.8	-	31.7	-
G. FREE SWELL (24-hr)	33	-	-	36	-	17	-
H. pH (initial/24-hr)	8.9/8.9	-	-	8.7/8.8	-	9.3/9.2	-
J. % RETAINED, #200 Sieve	2.7	-	-	1.6	-	2.1	-
K. TURBIDITY (NTU)	1012	-	-	892	-	1364	-
L. CRACKING PATTERN	U	-	-	U	-	SF	-
M. LIQUID LIMIT (%)	912	-	-	785	-	574	-

NOTE: -Key for cracking pattern test results: U (uniform), f (flocculated), C (cracked), P (pinholes), S (slight), and H (heavy)
-all slurries remixed immediately prior to testing

TABLE A-3. PRIMARY INDICATOR TEST RESULTS (Phase I)

Type: Polymer Protected	CHEMICALLY 'HYDRATED' Slurry						
Bentonite Id: 3	% ACETONE IN DEIONIZED WATER						
INDICATOR TEST	0 (BASELINE Slurry)	R_1	R_2	25	R1	75	R_1
A. MARSH FUNNEL VISCOSITY (sec)	59.5	-	-	82.4	-	25.8	-
B. GEL STRENGTH (lb/100 ft^2) - 10 sec	9.0	-	-	24.0	-	2.5	-
C. APPARENT VISCOSITY (cP)	18.5	-	-	38.5	-	3.0	-
D. YIELD POINT (lb/100 ft^2)	14.0	-	-	41.0	-	2.0	-
E. PLASTIC VISCOSITY (cP)	11.5	-	-	18.0	-	2.0	-
F. API FILTRATE LOSS (ml)	24.2	-	-	25.9	-	38.0	-
cake thickness [mm]	[3.0]	-	-	[4.0]	-	[3.0]	-
(ml/mm)	8.1	-	-	6.5	-	12.7	-
G. FREE SWELL (24-hr)	36	-	-	34	-	12	-
H. pH (initial/24-hr)	9.7/9.5	-	-	10.1/9.8	-	9.8/9.4	-
J. % RETAINED, #200 Sieve	2.9	-	-	3.4	-	1.5	-
K. TURBIDITY (NTU)	9.2	-	-	16	-	416	-
L. CRACKING PATTERN	U	-	-	SF	-	30% C	-
M. LIQUID LIMIT (%)	930	-	-	955	-	316	-

NOTE: -Key for cracking pattern test results: U (uniform), f (flocculated), C (cracked), P (pinholes), S (slight), and H (heavy)
-all slurries remixed immediately prior to testing

TABLE A-4. PRIMARY INDICATOR TEST RESULTS (Phase I)

Type: UNALTERED	CHEMICALLY 'HYDRATED' Slurry						
Bentonite Id: 4	% ACETONE IN DEIONIZED WATER						
INDICATOR TEST	0 (BASELINE Slurry)	R_1	R_2	25	R1	75	R_1
A. MARSH FUNNEL VISCOSITY (sec)	29.2	-	-	42.7	-	25.1	-
B. GEL STRENGTH (lb/100 ft^2) - 10 sec	3.5	-	-	6.0	-	2.5	-
C. APPARENT VISCOSITY (cP)	6.75	-	-	16.5	-	3.0	-
D. YIELD POINT (lb/100 ft^2)	4.5	-	-	11.0	-	3.0	-
E. PLASTIC VISCOSITY (cP)	4.5	-	-	11.0	-	3.0	-
F. API FILTRATE LOSS (ml)	24.4	-	-	19.0	-	52.0	-
cake thickness [mm]	[2.0]	-	-	[3.0]	-	[3.0]	-
(ml/mm)	12.2	-	-	6.3	-	18.7	-
G. FREE SWELL (24-hr)	30	-	-	42	-	12	-
H. pH (initial/24-hr)	9.4/9.3	-	-	9.7/90.5	-	9.6/9.4	-
J. % RETAINED, #200 Sieve	2.8	-	-	1.5	-	1.9	-
K. TURBIDITY (NTU)	228	-	-	276	-	552	-
L. CRACKING PATTERN	U			U	-	F	-
M. LIQUID LIMIT (%)	702	-	-	700	-	320	-

NOTE: -Key for cracking pattern test results: U (uniform), f (flocculated), C (cracked), P (pinholes), S (slight), and H (heavy)
-all slurries remixed immediately prior to testing

TABLE A-5. PRIMARY INDICATOR TEST RESULTS (Phase I)

Type: Chemically Treated	CHEMICALLY 'HYDRATED' Slurry						
Bentonite Id: 5	% ACETONE IN DEIONIZED WATER						
INDICATOR TEST	0 (BASELINE Slurry)	R_1	R_2	25	R1	75	R_1
A. MARSH FUNNEL VISCOSITY (sec)	31.0	—	—	60.3	—	25.8	—
B. GEL STRENGTH (lb/100 ft^2) - 10 min	3.0	—	—	7.0	—	3.0	—
C. APPARENT VISCOSITY (cP)	7.25	—	—	14.0	—	3.0	—
D. YIELD POINT (lb/100 ft^2)	3.5	—	—	16.0	—	2.0	—
E. PLASTIC VISCOSITY (cP)	5.5	—	—	12.0	—	2.0	—
F. API FILTRATE LOSS (ml)	16.9	—	—	18.2	—	31.4	—
cake thickness [mm]	[0.5]	—	—	[2.0]	—	[1.0]	—
(ml/mm)	33.8	—	—	9.1	—	31.4	—
G. FREE SWELL (24-hr)	20	—	—	20	—	12	—
H. pH (initial/24-hr)	8.3/7.8	—	—	8.6/8.4	—	9.3/9.1	—
J. % RETAINED, #200 Sieve	7.5	—	—	14.8	—	4.0	—
K. TURBIDITY (NTU)	1540	—	—	684	—	184	—
L. CRACKING PATTERN	U	—	—	SF&P	—	HF&P	—
M. LIQUID LIMIT (%)	433	—	—	721	—	304	—

NOTE: -Key for cracking pattern test results: U (uniform), f (flocculated), C (cracked), P (pinholes), S (slight), and H (heavy)
-all slurries remixed immediately prior to testing

TABLE A-6. PRIMARY INDICATOR TEST RESULTS (Phase I)

Type: Chemically Treated	CHEMICALLY 'HYDRATED' Slurry						
Bentonite Id: 6	% ACETONE IN DEIONIZED WATER						
INDICATOR TEST	0 (BASELINE Slurry)	R_1	R_2	25	R1	75	R_1
A. MARSH FUNNEL VISCOSITY (sec)	32.6	-	-	52.2	-	27.3	-
B. GEL STRENGTH (lb/100 ft^2) - 10 sec	2.5	-	-	6.0	-	4.0	-
C. APPARENT VISCOSITY (cP)	7.25	-	-	17.75	-	3.0	-
D. YIELD POINT (lb/100 ft^2)	3.5	-	-	10.5	-	3.0	-
E. PLASTIC VISCOSITY (cP)	5.5	-	-	12.5	-	1.5	-
F. API FILTRATE LOSS (ml)	14.4	-	-	14.1	-	27.8	-
cake thickness [mm]	[1.0]	-	-	[1.0]	-	[1.5]	-
(ml/mm)	14.4	-	-	14.1	-	18.5	-
G. FREE SWELL (24-hr)	22	-	-	24	-	14	-
H. pH (initial/24-hr)	7.6/7.5	-	-	8.2/8.1	-	8.9/9.5	-
J. % RETAINED, #200 Sieve	3.2	-	-	1.9	-	1.6	-
K. TURBIDITY (NTU)	1428	-	-	1096	-	436	-
L. CRACKING PATTERN	FC	-	-	HF	-	VHF	-
M. LIQUID LIMIT (%)	410	-	-	771	-	361	-

NOTE: -Key for cracking pattern test results: U (uniform), f (flocculated), C (cracked), P (pinholes), S (slight), and H (heavy)
-all slurries remixed immediately prior to testing

TABLE A-7. PRIMARY INDICATOR TEST RESULTS (Phase I)

Type: Polymer Extended	CHEMICALLY 'HYDRATED' Slurry						
Bentonite Id: 7	% ACETONE IN DEIONIZED WATER						
INDICATOR TEST	0 (BASELINE Slurry)	R_1	R_2	25	R1	75	R_1
A. MARSH FUNNEL VISCOSITY (sec)	37.5	-	-	83.4	-	26.4	-
B. GEL STRENGTH (lb/100 ft^2) - 10 sec	13.0	-	-	27.0	-	4.5	-
C. APPARENT VISCOSITY (cP)	17.5	-	-	23.5	-	3.5	-
D. YIELD POINT (lb/100 ft^2)	13.0	-	-	26.25	-	3.25	-
E. PLASTIC VISCOSITY (cP)	11.0	-	-	14.5	-	1.5	-
F. API FILTRATE LOSS (ml)	22.6	-	-	16.0	-	61.0	-
cake thickness [mm]	[3.0]	-	-	[3.5]	-	[3.5]	-
(ml/mm)	7.5	-	-	4.6	-	24.4	-
G. FREE SWELL (24-hr)	42	-	-	57	-	16	-
H. pH (initial/24-hr)	9.3/8.9	-	-	9.8/9.8	-	9.6/9.5	-
J. % RETAINED, #200 Sieve	1.4	-	-	0.7	-	0.5	-
K. TURBIDITY (NTU)	592	-	-	1272	-	722	-
L. CRACKING PATTERN	U	-	-	SF	-	SF	-
M. LIQUID LIMIT (%)	579	-	-	1070	-	387	-

NOTE: -Key for cracking pattern test results: U (uniform), f (flocculated), C (cracked), P (pinholes), S (slight), and H (heavy)
-all slurries remixed immediately prior to testing

TABLE A-8. PRIMARY INDICATOR TEST RESULTS (Phase I)

Type: Polymer Extended	CHEMICALLY 'HYDRATED' Slurry						
Bentonite Id: 8	% ACETONE IN DEIONIZED WATER						
INDICATOR TEST	0 (BASELINE Slurry)	R_1	R_2	25	R1	75	R_1
A. MARSH FUNNEL VISCOSITY (sec)	72.0	-	-	104.9	-	37.1	-
B. GEL STRENGTH (lb/100 ft^2) - 10 sec	24.0	21.0	-	21.0	-	19.0	6.0
C. APPARENT VISCOSITY (cP)	29.0	32.0	-	33.0	-	3.5	12.0
D. YIELD POINT (lb/100 ft^2)	30.0	33.0	-	30.0	-	3.0	11.0
E. PLASTIC VISCOSITY (cP)	14.0	15.5	-	18.0	-	2.0	6.5
F. API FILTRATE LOSS (ml)	20.1	-	-	15.3	-	48.6	-
cake thickness [mm]	[3.0]	-	-	[3.5]	-	[2.5]	-
(ml/mm)	6.7	-	-	4.4	-	19.4	-
G. FREE SWELL (24-hr)	4.1	-	-	55	-	16	-
H. pH (initial/24-hr)	9.3/8.7	-	-	9.4/9.1	-	9.4/9.4	-
J. % RETAINED, #200 Sieve	2.5	-	-	1.0	-	1.2	-
K. TURBIDITY (NTU)	2392	-	-	1064	-	1156	-
L. CRACKING PATTERN	U	-	-	SF	-	P	-
M. LIQUID LIMIT (%)	503	910	687	876	-	522	579

NOTE: -Key for cracking pattern test results: U (uniform), f (flocculated), C (cracked), P (pinholes), S (slight), and H (heavy)
-all slurries remixed immediately prior to testing

TABLE A-9. PRIMARY INDICATOR TEST RESULTS (Phase I)

Type:	CHEMICALLY 'HYDRATED' Slurry						
Bentonite Id: 9	% ACETONE IN DEIONIZED WATER						
INDICATOR TEST	0 (BASELINE Slurry)	R_1	R_2	25	R1	75	R_1
A. MARSH FUNNEL VISCOSITY (sec)	36.9	–	–	57.2	–	28.3	–
B. GEL STRENGTH (lb/100 ft^2) - 10 sec	4.0	–	–	13.0	–	2.0	–
C. APPARENT VISCOSITY (cP)	16.0	–	–	26.5	–	4.0	–
D. YIELD POINT (lb/100 ft^2)	10.0	–	–	23.0	–	0.0	–
E. PLASTIC VISCOSITY (cP)	11.0	–	–	15.0	–	4.0	–
F. API FILTRATE LOSS (ml)	12.0	–	–	9.8	–	20.0	–
cake thickness [mm]	[2.0]	–	–	[2.0]	–	[3.0]	–
(ml/mm)	6.0	–	–	4.9	–	6.7	–
G. FREE SWELL (24-hr)	44	–	–	54	–	15	–
H. pH (initial/24-hr)	9.1/8.8	–	–	9.1/8.9	–	9.4/9.3	–
J. % RETAINED, #200 Sieve	2.4	–	–	1.5	–	1.3	–
K. TURBIDITY (NTU)	1528	–	–	1060	–	1100	–
L. CRACKING PATTERN	U	–	–	SF	–	SF	–
M. LIQUID LIMIT (%)	511	646	675	874	–	880	–

NOTE: -Key for cracking pattern test results: U (uniform), f (flocculated), C (cracked), P (pinholes), S (slight), and H (heavy)
-all slurries remixed immediately prior to testing

TABLE A-10. PRIMARY INDICATOR TEST RESULTS (Phase I)

Type: Physically Altered Aniline Treated	CHEMICALLY 'HYDRATED' Slurry						
Bentonite Id: 10	% ACETONE IN DEIONIZED WATER						
INDICATOR TEST	0 (BASELINE Slurry)	R_1	R_2	25	R1	75	R_1
A. MARSH FUNNEL VISCOSITY (sec)	68.1	-	-	213.7	-	27.3	-
B. GEL STRENGTH (lb/100 ft^2) - 10 sec	4.0	-	-	10.0	-	3.5	-
C. APPARENT VISCOSITY (cP)	24.5	-	-	41.0	-	4.25	-
D. YIELD POINT (lb/100 ft^2)	20.0	-	-	27.0	-	3.5	-
E. PLASTIC VISCOSITY (cP)	14.5	-	-	27.5	-	2.5	-
F. API FILTRATE LOSS (ml)	9.4	-	-	7.3	-	21.2	-
cake thickness [mm]	[1.0]	-	-	[2.0]	-	[2.0]	-
(ml/mm)	9.4	-	-	3.7	-	10.6	-
G. FREE SWELL (24-hr)	44	-	-	54	-	25	-
H. pH (initial/24-hr)	9.0/8.8	-	-	9.4/9.2	-	9.3/9.3	-
J. % RETAINED, #200 Sieve	1.9	-	-	0.8	-	1.0	-
K. TURBIDITY (NTU)	1964	-	-	936	-	1108	-
L. CRACKING PATTERN	U	-	-	SF	-	40% C	-
M. LIQUID LIMIT (%)	736	-	-	1155	-	1108	-

NOTE: -Key for cracking pattern test results: U (uniform), f (flocculated), C (cracked), P (pinholes), S (slight), and H (heavy)
-all slurries remixed immediately prior to testing

TABLE A-11. PRIMARY INDICATOR TEST RESULTS (phase II)

Type: UNALTERED	CHEMICALLY 'HYDRATED' Slurry							
Bentonite: Id: 1	% ACETONE IN DEIONIZED WATER							
INDICATOR TEST	0 (BASELINE Slurry)	R_1	R_2	5	15	25	R_1	R_2
A. MARSH FUNNEL VISCOSITY (sec)	36.7	36.8	33.3	28.0	43.6	71.5	65.9	65.3
B. GEL STRENGTH (lb/100 ft^2)								
- 10 sec	0.8	1.0	0.5	0.0	7.5	14.0	12.0	11.0
- 10 min	6.3	9.0	4.0	0.0	9.0	21.0	22.0	24.0
C. APPARENT VISCOSITY (cP)	11.13	11.5	10.5	4.5	21.5	27.0	27.0	28.0
D. YIELD POINT (lb/100 ft^2)	4.8	5.0	4.0	1.0	13.0	20.0	18.0	20.0
E. PLASTIC VISCOSITY (cP)	9.3	9.0	9.0	4.0	15.0	17.0	18.0	18.0
F. FREE SWELL - 2 hr.	35.5	33.0	33.0	35.0	55.0	52.0	53.0	53.0
- 24 hr.	36.5	33.5	35.0	38.0	57.0	53.0	54.0	54.0
G. MUD WEIGHT (pcf)	64.8	64.8	64.5	63.1	63.3	63.3	63.3	63.0
H. SPECIFIC CONDUCTANCE (mmhos)	.942	.958	.877	.507	.707	.568	.516	.515
J. API FILTRATE LOSS								
(ml)	22.5	21.7	21.6	31.4	18.2	18.0	13.8	12.6
cake thickness [mm]	[2.3]	[2.7]	[2.5]	[1.8]	[2.9]	[3.2]	[1.6]	[1.7]
(ml/mm)	9.8	8.04	8.8	17.4	6.3	5.6	8.6	7.4
K. pH	9.8	9.8	9.8	10.2	9.9	1.0	9.7	9.9
Slurry Temperature (°C)	20.9	20.9	20.3	20.2	21.4	20.8	21.2	21.2
RUN:	1	2	3	4	5	6	7	8

NOTE: "Outlier" results in parentheses ( )
Slurry remixed immediately prior to test

(continued)

TABLE A-11 (continued)

Type: UNALTERED	WATER HYDRATED Chemical Slurry						
Bentonite: Id: 1	% ACETONE IN DEIONIZED WATER						
INDICATOR TEST	5	15	25	R_1	R_2	50	75*
A. MARSH FUNNEL VISCOSITY (sec)	35.9	39.5	39.3	42.6	47.3	51.7	32.1
B. GEL STRENGTH (lb/100 ft^2)							
- 10 sec	1.0	1.5	2.0	3.0	5.0	9.0	0.5
- 10 min	5.0	15.0	14.0	2.0	15.0	7.0	3.0
C. APPARENT VISCOSITY (cP)	13.5	17.0	18.5	19.0	20.5	22.0	8.5
D. YIELD POINT (lb/100 ft^2)	11.0	8.0	11.0	12.0	9.0	12.0	3.0
E. PLASTIC VISCOSITY (cP)	5.0	13.0	13.0	13.0	16.0	16.0	7.0
F. FREE SWELL - 2 hr.	--	--	--	--	--	--	--
- 24 hr.	--	--	--	--	--	--	--
G. MUD WEIGHT (pcf)	64.0	63.8	63.0	62.8	63.0	60.8	57.0
H. SPECIFIC CONDUCTANCE (mmhos)	.770	.661	.507	.528	.604	.387	.0722
J. API FILTRATE LOSS (ml)	18.3	17.0	15.8	15.7	16.0	13.7	20.2
cake thickness [mm]	[2.5]	[2.5]	[2.7]	[2.7]	[2.5]	[2.6]	[2.8]
(ml/mm)	7.3	6.8	5.8	5.8	6.4	5.3	7.2
K. pH	9.2	9.8	9.8	9.9	10.1	9.0	8.9
Slurry Temperature (°C)	22.0	22.2	22.4	22.4	22.3	21.3	21.2
RUN:	9	10	11	12	13	14	15

NOTE: "Outlier" results in parentheses ( )
Slurry remixed immediately prior to test
*A paste of lower moisture content was used to prepare the 75% slurry

TABLE A-12. PRIMARY INDICATOR TEST RESULTS (phase II)

Type: UNALTERED	CHEMICALLY 'HYDRATED' Slurry							
Bentonite: Id: 2	% ACETONE IN DEIONIZED WATER							
INDICATOR TEST	0 (BASELINE Slurry)	R_1	R_2	5	15	25	R_1	R_2
A. MARSH FUNNEL VISCOSITY (sec)	44.7	--	--	31.8	49.4	42.5	--	--
B. GEL STRENGTH (lb/100 ft^2)								
- 10 sec	1.5	--	--	0.0	1.0	0.8	--	--
- 10 min	5.0	--	--	0.0	3.0	0.8	--	--
C. APPARENT VISCOSITY (cP)	20.5	--	--	6.5	25.5	24.5	--	--
D. YIELD POINT (lb/100 ft^2)	13.0	--	--	3.0	15.0	9.0	--	--
E. PLASTIC VISCOSITY (cP)	14.0	--	--	5.0	18.0	20.0	--	--
F. FREE SWELL - 2 hr.	23.0	--	--	22.0	26.0	25.0	--	--
- 24 hr.	23.0	--	--	22.0	27.0	26.0	--	--
G. MUD WEIGHT (pcf)	64.3	--	--	63.2	63.95	63.4	--	--
H. SPECIFIC CONDUCTANCE (mmhos)	.891	--	--	.513	.565	.496	--	--
J. API FILTRATE LOSS (ml)	15.6	--	--	17.5	13.2	12.0	--	--
cake thickness [mm]	[2.7]	--	--	[1.4]	[2.4]	[3.4]	--	--
(ml/mm)	5.8	--	--	12.5	5.5	5.0	--	--
K. pH	9.6	--	--	1.0	9.6	8.35	--	--
Slurry Temperature (°C)	21.2	--	--	20.2	20.8	21.4	--	--
RUN:	1	2	3	4	5	6	7	8

(continued)

NOTE: "Outlier" results in parentheses ( )
Slurry remixed immediately prior to test

TABLE A-12 (continued)

Type: UNALTERED	WATER HYDRATED Chemical Slurry						
Bentonite: Id: 2	% ACETONE IN DEIONIZED WATER						
INDICATOR TEST	5	15	25	R_1	R_2	50	75*
A. MARSH FUNNEL VISCOSITY (sec)	36.1	35.5	42.7	--	--	38.0	30.9
B. GEL STRENGTH (lb/100 ft^2)							
- 10 sec	0.5	0.0	0.0	--	--	0.5	0.0
- 10 min	0.5	0.35	1.0	--	--	6.0	4.0
C. APPARENT VISCOSITY (cP)	14.5	16.0	17.0	--	--	12.0	7.0
D. YIELD POINT (lb/100 ft^2)	5.0	6.0	6.0	--	--	4.0	2.0
E. PLASTIC VISCOSITY (cP)	12.0	13.0	14.0	--	--	10.0	6.0
F. FREE SWELL - 2 hr.	--	--	--	--	--	--	--
- 24 hr.	--	--	--	--	--	--	--
G. MUD WEIGHT (pcf)	64.0	63.5	62.5	--	--	60.5	57.0
H. SPECIFIC CONDUCTANCE (mmhos)	.707	.544	.500	--	--	.334	94.6
J. API FILTRATE LOSS (ml)	14.2	12.6	11.8	--	--	11.6	18.7
cake thickness [mm]	[1.6]	[1.7]	[1.6]	--	--	[2.4]	[2.5]
(ml/mm)	8.9	7.4	7.4	--	--	4.8	7.5
K. pH	9.5	9.6	9.3	--	--	7.9	8.0
Slurry Temperature (°C)	22.6	22.7	22.4	--	--	21.4	21.5
RUN:	9	10	11	12	13	14	15

NOTE: "Outlier" results in parentheses ( )
Slurry remixed immediately prior to test
*A paste of lower moisture content was used to prepare the 75% slurry

TABLE A-13. PRIMARY INDICATOR TEST RESULTS (phase II)

Type: POLYMER PROTECTED	CHEMICALLY 'HYDRATED' Slurry							
Bentonite: Id: 3	% ACETONE IN DEIONIZED WATER							
INDICATOR TEST	0 (BASELINE Slurry)	R_1	R_2	5	15	25	R_1	R_2
A. MARSH FUNNEL VISCOSITY (sec)	112.5	110.4	(59.6)	84.2	57.3	93.0	86.5	104.3
B. GEL STRENGTH (lb/100 ft^2)								
- 10 sec	7.8	7.0	(5.0)	19.0	14.5	20.0	20.0	21.0
- 10 min	10.0	12.0	12.5	19.0	17.0	20.0	20.0	21.0
C. APPARENT VISCOSITY (cP)	28.3	28.5	28.5	29.5	33.5	38.0	39.0	42.5
D. YIELD POINT (lb/100 ft^2)	19.0	20.0	(12.0)	25.0	31.0	38.0	38.0	41.0
E. PLASTIC VISCOSITY (cP)	18.8	18.5	22.5	17.0	18.0	19.0	20.0	22.0
F. FREE SWELL - 2 hr.	(40.0)	31.0	30.5	27.5	47.0	39.0	39.0	39.0
- 24 hr.	(41.0)	32.5	32.0	29.0	48.5	42.0	42.0	42.5
G. MUD WEIGHT (pcf)	64.5	64.5	64.5	64.3	63.8	63.3	63.3	63.8
H. SPECIFIC CONDUCTANCE (mmhos)	.977	.967	.991	.858	.750	.562	.585	.502
J. API FILTRATE LOSS								
(ml)	23.6	20.4	20.3	24.0	21.0	22.7	22.7	22.0
cake thickness [mm]	[3.4]	[3.3]	[4.1]	[5.1]	[4.8]	[3.5]	[3.5]	[3.6]
(ml/mm)	6.9	6.2	4.9	4.7	4.4	6.5	6.5	6.1
K. pH	10.2	10.2	10.2	10.4	10.4	10.5	10.6	10.5
Slurry Temperature (°C)	20.7	20.8	21.3	21.2	21.4	21.4	21.2	20.1
RUN:	1	2	3	4	5	6	7	8

NOTE: "Outlier" results in parentheses ( )
Slurry remixed immediately prior to test

(continued)

TABLE A-13 (continued)

Type: POLYMER PROTECTED	WATER HYDRATED Chemical Slurry						
Bentonite Id: 3	% ACETONE IN DEIONIZED WATER						
INDICATOR TEST	5	15	25	R_1	R_2	50	75*
A. MARSH FUNNEL VISCOSITY (sec)	91.1	203.6	89.5	107.1	99.6	96.9	26.6
B. GEL STRENGTH (lb/100 ft^2)							
- 10 sec	16.0	28.0	17.0	19.0	20.0	14.0	0.0
- 10 min	27.0	36.0	23.0	28.0	30.0	14.0	1.0
C. APPARENT VISCOSITY (cP)	36.5	45.5	46.0	47.0	48.0	43.0	4.5
D. YIELD POINT (lb/100 ft^2)	33.0	43.0	40.0	38.0	36.0	38.0	1.0
E. PLASTIC VISCOSITY (cP)	20.0	24.0	26.0	28.0	30.0	24.0	4.0
F. FREE SWELL - 2 hr.	--	--	--	--	--	--	--
- 24 hr.	--	--	--	--	--	--	--
G. MUD WEIGHT (pcf)	63.8	63.8	63.8	63.8	64.0	60.8	56.8
H. SPECIFIC CONDUCTANCE (mmhos)	.810	.685	.547	.580	.580	.328	.0778
J. API FILTRATE LOSS (ml)	18.2	18.3	19.0	20.2	20.1	18.6	49.8
cake thickness [mm]	[3.6]	[4.0]	[3.7]	[3.9]	[3.5]	[5.0]	[4.1]
(ml/mm)	5.1	4.6	5.1	5.2	5.7	3.7	12.1
K. pH	10.1	10.2	10.4	10.5	10.6	9.3	9.3
Slurry Temperature (°C)	21.9	22.0	22.0	21.8	21.9	21.4	21.7
RUN:	9	10	11	12	13	14	15

NOTE: "Outlier" results in parentheses ( )
Slurry remixed immediately prior to test
*A paste of lower moisture content was used to prepare the 75% slurry

TABLE A-14. PRIMARY INDICATOR TEST RESULTS (phase II)

Type: UNALTERED	CHEMICALLY 'HYDRATED' Slurry							
Bentonite Id: 4	% ACETONE IN DEIONIZED WATER							
INDICATOR TEST	0 (BASELINE Slurry)	R_1	R_2	5	15	25	R_1	R_2
A. MARSH FUNNEL VISCOSITY (sec)	32.0	--	--	31.2	39.5	42.1	--	--
B. GEL STRENGTH (lb/100 ft^2)								
- 10 sec	0.3	--	--	0.5	2.5	3.0	--	--
- 10 min	3.0	--	--	6.0	7.5	8.0	--	--
C. APPARENT VISCOSITY (cP)	9.625	--	--	12.5	17.5	20.0	--	--
D. YIELD POINT (lb/100 ft^2)	3.3	--	--	5.0	9.0	10.0	--	--
E. PLASTIC VISCOSITY (cP)	8.0	--	--	10.0	13.0	15.0	--	--
F. FREE SWELL - 2 hr.	31.0	--	--	24.0	40.0	32.0	--	--
- 24 hr.	32.0	--	--	26.0	41.0	36.0	--	--
G. MUD WEIGHT (pcf)	64.6	--	--	64.3	65.3	63.0	--	--
H. SPECIFIC CONDUCTANCE (mmhos)	.755	--	--	.732	.522	.431	--	--
J. API FILTRATE LOSS								
(ml)	23.4	--	--	21.9	20.3	18.0	--	--
cake thickness [mm]	[2.0]	--	--	[2.8]	[2.4]	[2.5]	--	--
(ml/mm)	11.7	--	--	7.8	8.5	7.2	--	--
K. pH	10.2	--	--	10.1	10.2	10.2	--	--
Slurry Temperature (°C)	21.1	--	--	21.0	21.0	21.2	--	--
RUN:	1	2	3	4	5	6	7	8

NOTE: "Outlier" results in parentheses ( )
Slurry remixed immediately prior to test

(continued)

TABLE A-14 (continued)

Type: UNALTERED	WATER HYDRATED Chemical Slurry						
Bentonite Id: 4	% ACETONE IN DEIONIZED WATER						
INDICATOR TEST	5	15	25	R1	R2	50	75*
A. MARSH FUNNEL VISCOSITY (sec)	41.5	44.2	47.0	--	--	41.9	34.7
B. GEL STRENGTH (lb/100 ft^2)							
- 10 sec	0.0	0.3	0.8	--	--	4.0	1.0
- 10 min	3.0	2.0	9.0	--	--	4.0	3.0
C. APPARENT VISCOSITY (cP)	13.5	22.5	23.5	--	--	19.0	7.5
D. YIELD POINT (lb/100 ft^2)	9.0	9.0	9.0	--	--	8.0	5.0
E. PLASTIC VISCOSITY (cP)	9.0	18.0	19.0	--	--	15.0	5.0
F. FREE SWELL - 2 hr.	--	--	--	--	--	--	--
- 24 hr.	--	--	--	--	--	--	--
G. MUD WEIGHT (pcf)	64.5	63.8	63.8	--	--	60.5	56.8
H. SPECIFIC CONDUCTANCE (mmhos)	.728	.558	.464	--	--	.265	.0608
J. API FILTRATE LOSS (ml)	17.0	16.0	15.4	--	--	14.0	25.0
cake thickness [mm]	[2.4]	[2.6]	[2.6]	--	--	[2.4]	[2.0]
(ml/mm)	7.1	6.2	5.9	--	--	5.8	12.5
K. pH	9.9	10.2	10.2	--	--	9.3	9.7
Slurry Temperature (°C)	23.4	23.3	23.3	--	--	21.4	21.6
RUN:	9	10	11	12	13	14	15

NOTE: "Outlier" results in parentheses ( )
Slurry remixed immediately prior to test
*A paste of lower moisture content was used to prepare the 75% slurry

TABLE A-15. PRIMARY INDICATOR TEST RESULTS (phase II)

Type: CHEMICALLY TREATED	CHEMICALLY 'HYDRATED' Slurry							
Bentonite Id: 5	% ACETONE IN DEIONIZED WATER							
INDICATOR TEST	0 (BASELINE Slurry)	R_1	R_2	5	15	25	R_1	R_2
A. MARSH FUNNEL VISCOSITY (sec)	31.7	29.6	32.3	32.8	31.1	31.3	36.3	37.2
B. GEL STRENGTH (lb/100 ft^2)								
- 10 sec	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
- 10 min	0.0	0.2	0.0	0.0	0.5	0.0	0.0	0.0
C. APPARENT VISCOSITY (cP)	6.25	6.5	6.0	7.8	8.0	12.0	12.0	12.0
D. YIELD POINT (lb/100 ft^2)	0.5	0.0	0.0	1.5	2.0	11.0	11.0	12.0
E. PLASTIC VISCOSITY (cP)	6.0	6.5	6.0	7.0	7.0	2.0	2.0	1.0
F. FREE SWELL - 2 hr.	15.0	14.0	15.0	17.0	17.0	16.0	15.0	15.0
- 24 hr.	17.0	14.0	16.0	18.0	19.0	18.0	18.0	18.0
G. MUD WEIGHT (pcf)	64.25	64.3	64.3	64.3	63.3	62.8	63.0	62.8
H. SPECIFIC CONDUCTANCE (mmhos)	.930	.950	.820	.823	.601	.418	.418	.469
J. API FILTRATE LOSS (ml)	11.3	4.8	15.9	16.3	14.7	16.5	16.6	16.3
cake thickness [mm]	[1.5]	[1.2]	[1.6]	[1.7]	[1.8]	[4.2]	[3.5]	[3.4]
(ml/mm)	7.5	4.0	9.9	9.6	8.2	3.9	4.7	4.8
K. pH	8.7	8.7	8.7	8.5	8.7	9.3	9.1	8.5
Slurry Temperature (°C)	22.0	22.1	22.2	20.7	21.4	21.4	21.4	20.3
RUN:	1	2	3	4	5	6	7	8

(continued)

NOTE: "Outlier" results in parentheses ( )
Slurry remixed immediately prior to test

TABLE A-15 (continued)

Type: CHEMICALLY TREATED	WATER HYDRATED Chemical Slurry						
Bentonite Id: 5	% ACETONE IN DEIONIZED WATER						
INDICATOR TEST	5	15	25	R_1	R_2	50	75*
A. MARSH FUNNEL VISCOSITY (sec)	28.2	36.8	45.9	45.9	36.1	36.6	30.7
B. GEL STRENGTH (lb/100 ft^2)							
- 10 sec	0.0	0.3	4.0	5.0	5.0	3.0	0.0
- 10 min	0.0	3.0	15.0	14.5	12.0	7.0	0.3
C. APPARENT VISCOSITY (cP)	8.0	11.5	18.5	18.5	16.0	14.0	5.5
D. YIELD POINT (lb/100 ft^2)	2.0	10.0	11.0	11.0	8.0	6.0	1.0
E. PLASTIC VISCOSITY (cP)	7.0	11.0	13.0	13.0	12.0	11.0	6.0
F. FREE SWELL - 2 hr.	--	--	--	--	--	--	--
- 24 hr.	--	--	--	--	--	--	--
G. MUD WEIGHT (pcf)	63.5	63.3	62.8	63.3	62.5	60.8	56.8
H. SPECIFIC CONDUCTANCE (mmhos)	.872	.743	.623	.633	.547	.486	.0925
J. API FILTRATE LOSS							
(ml)	16.5	16.0	14.0	14.2	15.5	15.0	25.8
cake thickness [mm]	[1.8]	[1.9]	[2.0]	[1.6]	[2.8]	[1.3]	2.0
(ml/mm)	9.2	8.4	7.0	8.9	8.6	11.5	12.9
K. pH	8.5	8.5	8.3	8.4	8.4	7.4	7.9
Slurry Temperature (°C)	23.0	23.3	21.8	21.8	21.7	21.6	22.5
RUN:	9	10	11	12	13	14	15

NOTE: "Outlier" results in parentheses ( )
Slurry remixed immediately prior to test
*A paste of lower moisture content was used to prepare the 75% slurry

TABLE A-16. PRIMARY INDICATOR TEST RESULTS (phase II)

Type: CHEMICALLY TREATED	CHEMICALLY 'HYDRATED' Slurry							
Bentonite Id: 6	% ACETONE IN DEIONIZED WATER							
INDICATOR TEST	0 (BASELINE Slurry)	R_1	R_2	5	15	25	R_1	R_2
A. MARSH FUNNEL VISCOSITY (sec)	34.0	--	--	30.0	33.5	41.2	--	--
B. GEL STRENGTH (lb/100 ft^2)								
- 10 sec	0.5	--	--	0.0	0.5	1.0	--	--
- 10 min	0.0	--	--	0.0	0.0	2.0	--	--
C. APPARENT VISCOSITY (cP)	8.5	--	--	11.0	15.5	20.5	--	--
D. YIELD POINT (lb/100 ft^2)	0.0	--	--	12.0	5.0	9.0	--	--
E. PLASTIC VISCOSITY (cP)	8.5	--	--	5.0	13.0	16.0	--	--
F. FREE SWELL - 2 hr.	16.0	--	--	16.0	20.0	15.0	--	--
- 24 hr.	17.0	--	--	18.0	21.5	17.0	--	--
G. MUD WEIGHT (pcf)	64.5	--	--	64.1	63.8	62.8	--	--
H. SPECIFIC CONDUCTANCE (mmhos)	1.252	--	--	1.057	.755	.511	--	--
J. API FILTRATE LOSS								
(ml)	13.4	--	--	13.3	12.3	12.8	--	--
cake thickness [mm]	[0.9]	--	--	[1.8]	[1.6]	[1.4]	--	--
(ml/mm)	14.8	--	--	7.4	7.7	9.1	--	--
K. pH	7.4	--	--	7.4	7.7	7.4	--	--
Slurry Temperature (°C)	22.0	--	--	20.7	20.5	20.8	--	--
RUN:	1	2	3	4	5	6	7	8

NOTE: "Outlier" results in parentheses ( )
Slurry remixed immediately prior to test

(continued)

TABLE A-16 (continued)

Type: CHEMICALLY TREATED	WATER HYDRATED Chemical Slurry						
Bentonite Id: 6	% ACETONE IN DEIONIZED WATER						
INDICATOR TEST	5	15	25	R_1	R_2	50	75*
A. MARSH FUNNEL VISCOSITY (sec)	67.8	74.3	148.6	--	--	33.9	27.0
B. GEL STRENGTH (lb/100 ft^2)							
- 10 sec	4.0	5.0	18.5	--	--	0.0	1.3
- 10 min	20.5	20.4	20.5	--	--	1.5	3.0
C. APPARENT VISCOSITY (cP)	44.5	41.5	59.5	--	--	13.5	5.0
D. YIELD POINT (lb/100 ft^2)	31.0	29.0	45.0	--	--	3.0	2.0
E. PLASTIC VISCOSITY (cP)	29.0	27.0	37.0	--	--	12.0	4.0
F. FREE SWELL - 2 hr.	--	--	--	--	--	--	--
- 24 hr.	--	--	--	--	--	--	--
G. MUD WEIGHT (pcf)	64.7	63.5	63.3	--	--	60.0	57.0
H. SPECIFIC CONDUCTANCE (mmhos)	.648	.568	.499	--	--	.428	.1501
J. API FILTRATE LOSS (ml)	5.7	6.6	7.1	--	--	13.1	27.8
cake thickness [mm]	[2.3]	[1.9]	[2.2]	--	--	[1.3]	[2.2]
(ml/mm)	2.5	3.5	3.2	--	--	10.5	12.6
K. pH	9.4	9.7	9.7	--	--	7.4	7.0
Slurry Temperature (°C)	20.4	20.4	20.5	--	--	22.0	22.0
RUN:	9	10	11	12	13	14	15

NOTE: "Outlier" results in parentheses ( )
Slurry remixed immediately prior to test
*A paste of lower moisture content was used to prepare the 75% slurry

TABLE A-17. PRIMARY INDICATOR TEST RESULTS (phase II)

Type: POLYMER EXTENDED	CHEMICALLY 'HYDRATED' Slurry							
Bentonite Id: 7	% ACETONE IN DEIONIZED WATER							
INDICATOR TEST	0 (BASELINE Slurry)	R_1	R_2	5	15	25	R_1	R_2
A. MARSH FUNNEL VISCOSITY (sec)	46.9	42.1	43.6	58.4	136.9	95.4	119.4	108.4
B. GEL STRENGTH (lb/100 ft^2)								
- 10 sec	5.0	5.0	3.0	12.5	21.5	17.0	20.0	18.0
- 10 min	17.0	17.0	17.0	13.5	31.0	21.0	23.0	22.0
C. APPARENT VISCOSITY (cP)	20.3	20.3	19.8	29.0	35.5	35.5	35.0	33.0
D. YIELD POINT (lb/100 ft^2)	13.5	13.5	10.5	22.0	31.0	31.0	30.0	30.0
E. PLASTIC VISCOSITY (cP)	13.5	13.5	14.5	18.0	20.0	19.0	20.0	18.0
F. FREE SWELL - 2 hr.	36.0	38.5	38.0	40.0	48.0	52.0	53.0	53.0
- 24 hr.	38.0	39.5	38.5	42.0	52.0	53.0	53.0	53.5
G. MUD WEIGHT (pcf)	64.3	64.5	64.6	64.3	64.3	64.3	63.3	63.0
H. SPECIFIC CONDUCTANCE (mmhos)	.803	.835	.880	.831	.610	.475	.526	.496
J. API FILTRATE LOSS								
(ml)	19.6	20.6	17.9	19.2	15.0	15.4	15.6	15.2
cake thickness [mm]	[4.2]	[4.5]	[3.3]	[3.7]	[2.7]	[4.1]	[4.3]	[4.0]
(ml/mm)	4.7	4.6	5.4	5.2	5.6	3.7	3.6	3.8
K. pH	9.8	9.9	9.7	10.1	10.0	9.9	9.9	10.2
Slurry Temperature (°C)	22.6	22.8	22.8	21.4	20.6	20.5	20.6	20.7
RUN:	1	2	3	4	5	6	7	8

NOTE: "Outlier" results in parentheses ( )
Slurry remixed immediately prior to test

(continued)

TABLE A-17 (continued)

Type: POLYMER EXTENDED	WATER HYDRATED Chemical Slurry						
Bentonite Id: 7	% ACETONE IN DEIONIZED WATER						
INDICATOR TEST	5	15	25	R_1	R_2	50	75*
A. MARSH FUNNEL VISCOSITY (sec)	46.6	64.5	89.1	72.4	73.4	115.2	38.7
B. GEL STRENGTH (lb/100 ft^2)							
- 10 sec	2.0	7.5	9.0	10.0	8.0	37.0	8.0
- 10 min	5.0	21.0	26.0	28.0	27.0	45.0	15.0
C. APPARENT VISCOSITY (cP)	22.0	30.5	32.5	32.5	33.0	32.5	15.5
D. YIELD POINT (lb/100 ft^2)	14.0	19.0	23.0	23.0	24.0	45.0	13.0
E. PLASTIC VISCOSITY (cP)	15.0	21.0	21.0	21.0	21.0	10.0	9.0
F. FREE SWELL - 2 hr.	-	-	-	-	-	-	-
- 24 hr.	-	-	-	-	-	-	-
G. MUD WEIGHT (pcf)	64.0	63.5	63.0	62.8	63.0	60.5	56.8
H. SPECIFIC CONDUCTANCE (mmhos)	.770	.558	.474	.494	.527	.375	.0794
J. API FILTRATE LOSS							
(ml)	19.0	21.5	19.0	21.0	19.5	13.4	20.8
cake thickness [mm]	[3.3]	[3.5]	[2.6]	[2.9]	[3.1]	2.7	2.7
(ml/mm)	5.8	6.1	7.3	7.2	6.3	5.0	7.7
K. pH	9.6	9.9	10.0	10.0	10.0	9.5	9.2
Slurry Temperature (°C)	21.8	21.8	21.8	21.8	21.6	21.8	22.3
RUN:	9	10	11	12	13	14	15

NOTE: "Outlier" results in parentheses ( )
Slurry remixed immediately prior to test
*A paste of lower moisture content was used to prepare the 75% slurry

TABLE A-18. PRIMARY INDICATOR TEST RESULTS (phase II)

Type: POLYMER EXTENDED	CHEMICALLY 'HYDRATED' Slurry							
Bentonite Id: 8	% ACETONE IN DEIONIZED WATER							
INDICATOR TEST	0 (BASELINE Slurry)	R_1	R_2	5	15	25	R_1	R_2
A. MARSH FUNNEL VISCOSITY (sec)	112.5	--	--	187.0	210.0	184.0	--	--
B. GEL STRENGTH (lb/100 ft^2)								
- 10 sec	24.0	--	--	32.0	30.0	22.0	--	--
- 10 min	26.0	--	--	38.0	46.0	31.0	--	--
C. APPARENT VISCOSITY (cP)	43.0	--	--	53.0	55.5	46.0	--	--
D. YIELD POINT (lb/100 ft^2)	46.0	--	--	50.0	59.0	50.0	--	--
E. PLASTIC VISCOSITY (cP)	20.0	--	--	23.0	26.0	21.0	--	--
F. FREE SWELL - 2 hr.	32.0	--	--	35.0	48.0	46.0	--	--
- 24 hr.	32.5	--	--	37.0	51.0	47.0	--	--
G. MUD WEIGHT (pcf)	64.5	--	--	64.5	63.8	63.0	--	--
H. SPECIFIC CONDUCTANCE (mmhos)	.792	--	--	.713	.544	.481	--	--
J. API FILTRATE LOSS (ml)	16.2	--	--	14.5	14.8	13.5	--	--
cake thickness [mm]	[2.2]	--	--	[3.5]	[3.1]	[2.6]	--	--
(ml/mm)	7.5	--	--	4.1	4.8	5.2	--	--
K. pH	9.8	--	--	10.0	10.1	9.9	--	--
Slurry Temperature (°C)	23.2	--	--	21.2	20.5	20.4	--	--
RUN:	1	2						

TABLE A-18 (continued)

Type: POLYMER EXTENDED	WATER HYDRATED Chemical Slurry						
Bentonite Id: 8	% ACETONE IN DEIONIZED WATER						
INDICATOR TEST	5	15	25	R_1	R_2	50	75*
A. MARSH FUNNEL VISCOSITY (sec)	38.7	50.3	45.5	--	--	56.0	35.5
B. GEL STRENGTH (lb/100 ft^2)							
- 10 sec	1.5	2.0	2.0	--	--	5.0	0.0
- 10 min	4.0	4.5	11.0	--	--	15.0	3.0
C. APPARENT VISCOSITY (cP)	21.0	25.0	27.0	--	--	27.5	10.5
D. YIELD POINT (lb/100 ft^2)	14.0	14.0	16.0	--	--	17.0	5.0
E. PLASTIC VISCOSITY (cP)	14.0	18.0	19.0	--	--	19.0	8.0
F. FREE SWELL - 2 hr.	--	--	--	--	--	--	--
- 24 hr.	--	--	--	--	--	--	--
G. MUD WEIGHT (pcf)	64.0	63.3	62.3	--	--	60.5	57.0
H. SPECIFIC CONDUCTANCE (mmhos)	.597	.508	.410	--	--	.313	.0706
J. API FILTRATE LOSS (ml)	15.6	14.0	13.4	--	--	13.2	20.2
cake thickness [mm]	[2.0]	[2.0]	[2.5]	--	--	[2.6]	[2.7]
(ml/mm)	7.8	7.0	6.2	--	--	5.1	7.5
K. pH	9.6	9.9	9.9	--	--	8.63	8.8
Slurry Temperature (°C)	21.0	20.7	20.8	--	--	22.5	22.2
RUN:	9	10	11	12	13	14	15

NOTE: "Outlier" results in parentheses ( )
Slurry remixed immediately prior to test
*A paste of lower moisture content was used to prepare the 75% slurry

TABLE A-19. PRIMARY INDICATOR TEST RESULTS (phase II)

Type: PHYSICALLY ALTERED	CHEMICALLY 'HYDRATED' Slurry							
Bentonite Id: 9	% ACETONE IN DEIONIZED WATER							
INDICATOR TEST	0 (BASELINE Slurry)	R_1	R_2	5	15	25	R_1	R_2
A. MARSH FUNNEL VISCOSITY (sec)	36.7	39.0	35.2	41.3	48.6	51.0	52.2	52.9
B. GEL STRENGTH (lb/100 ft^2)								
- 10 sec	1.0	0.5	0.8	0.0	1.0	19.0	21.0	3.0
- 10 min	2.0	1.5	2.0	2.5	5.5	35.0	36.0	8.0
C. APPARENT VISCOSITY (cP)	16.0	16.0	14.8	18.5	25.0	44.0	45.0	(30.0)
D. YIELD POINT (lb/100 ft^2)	6.0	7.0	6.5	9.0	12.0	44.0	48.0	18.0
E. PLASTIC VISCOSITY (cP)	13.0	12.5	11.5	14.0	19.0	22.0	21.0	21.0
F. FREE SWELL - 2 hr.	22.0	27.0	25.0	23.0	39.0	37.0	37.0	38.0
- 24 hr.	25.0	28.0	26.0	25.0	40.0	37.0	38.0	39.0
G. MUD WEIGHT (pcf)	64.5	64.5	64.8	63.3	63.0	62.8	62.8	62.8
H. SPECIFIC CONDUCTANCE (mmhos)	.737	.842	.737	.700	.541	.422	.434	.400
J. API FILTRATE LOSS								
(ml)	10.8	11.0	11.5	8.0	10.3	9.0	8.4	9.5
cake thickness [mm]	[1.1]	[2.0]	[1.6]	[1.8]	[1.8]	[2.5]	[2.6]	[3.3]
(ml/mm)	9.8	5.5	7.2	4.4	5.7	3.6	3.2	2.9
K. pH	9.5	9.7	9.6	9.7	10.0	10.0	10.1	9.7
Slurry Temperature (°C)	22.4	22.4	22.3	21.5	20.5	30.2	20.2	20.6
RUN:	1	2	3	4	5	6	7	8

NOTE: "Outlier" results in parentheses ( )
Slurry remixed immediately prior to test

(continued)

TABLE A-19 (continued)

Type: PHYSICALLY ALTERED	WATER HYDRATED Chemical Slurry						
Bentonite Id: 9	% ACETONE IN DEIONIZED WATER						
INDICATOR TEST	5	15	25	R_1	R_2	50	75*
A. MARSH FUNNEL VISCOSITY (sec)	35.9	41.2	47.4	43.2	49.4	68.0	44.8
B. GEL STRENGTH (lb/100 ft^2)							
- 10 sec	1.0	1.5	2.0	1.3	1.0	1.0	2.0
- 10 min	2.0	2.5	5.0	8.0	8.0	40.0	21.0
C. APPARENT VISCOSITY (cP)	17.0	21.0	24.0	25.5	23.5	30.0	19.0
D. YIELD POINT (lb/100 ft^2)	8.0	12.0	12.0	13.0	11.0	20.0	8.0
E. PLASTIC VISCOSITY (cP)	13.0	15.0	19.0	19.0	18.0	20.0	15.0
F. FREE SWELL - 2 hr.	--	--	--	--	--	--	--
- 24 hr.	--	--	--	--	--	--	--
G. MUD WEIGHT (pcf)	64.0	63.5	62.8	62.5	62.5	60.3	57.0
H. SPECIFIC CONDUCTANCE (mmhos)	.639	.508	.450	.451	.410	.326	.0849
J. API FILTRATE LOSS (ml)	10.6	9.6	8.4	8.6	8.5	8.0	12.6
cake thickness [mm]	[2.0]	[1.6]	[1.9]	[2.7]	[1.6]	[2.3]	[2.2]
(ml/mm)	5.3	6.0	4.4	3.2	5.3	3.5	5.7
K. pH	9.6	9.8	10.0	9.9	9.7	9.4	8.8
Slurry Temperature (°C)	2	2.5	5	8	8	40	21
RUN:	9	10	11	12	13	14	15

NOTE: "Outlier" results in parentheses ( )
Slurry remixed immediately prior to test
*A paste of lower moisture content was used to prepare the 75% slurry

TABLE A-20 PRIMARY INDICATOR TEST RESULTS (phase II)

Type: PHYSICALLY ALTERED AMINE TREATED	CHEMICALLY 'HYDRATED' Slurry							
Bentonite Id: 10	% ACETONE IN DEIONIZED WATER							
INDICATOR TEST	0 (BASELINE Slurry)	R_1	R_2	5	15	25	R_1	R_2
A. MARSH FUNNEL VISCOSITY (sec)	49.2	46.2	45.6	48.3	63.7	120.9	161.3	115.9
B. GEL STRENGTH (lb/100 ft^2)								
- 10 sec	3.0	0.0	2.0	3.0	1.5	7.0	4.0	5.0
- 10 min	5.0	2.0	3.0	4.0	7.0	28.0	34.0	30.0
C. APPARENT VISCOSITY (cP)	26.0	26.8	24.0	32.5	39.5	57.0	50.5	54.0
D. YIELD POINT (lb/100 ft^2)	16.0	17.5	15.0	19.0	23.0	32.0	33.0	32.0
E. PLASTIC VISCOSITY (cP)	18.0	18.0	16.5	23.0	28.0	41.0	39.0	38.0
F. FREE SWELL - 2 hr.	33.0	31.0	32.0	34.0	33.0	41.0	42.0	42.0
- 24 hr.	34.5	32.0	33.0	36.0	35.0	42.0	43.5	43.5
G. MUD WEIGHT (pcf)	64.8	64.8	64.8	64.3	63.5	62.8	63.0	62.8
H. SPECIFIC CONDUCTANCE (mmhos)	.794	.741	.839	.720	.547	.408	.407	(.278)
J. API FILTRATE LOSS								
(ml)	8.8	8.7	(10.8)	9.2	7.7	7.5	6.7	6.8
cake thickness [mm]	[2.3]	[1.7]	[1.8]	[1.8]	[2.1]	[2.4]	[3.3]	[3.0]
(ml/mm)	3.8	5.1	6.0			3.1	2.0	2.3
K. pH	9.5	9.6	9.6	9.6	9.8	9.6	9.7	10.1
Slurry Temperature (°C)	22.4	22.4	22.3	21.8	20.8	20.1	20.0	20.6
RUN:	1	2	3	4	5	6	7	8

NOTE: "Outlier" results in parentheses ( )
Slurry remixed immediately prior to test

(continued)

TABLE A-20 (continued)

Type: PHYSICALLY ALTERED AMINE TREATED	WATER HYDRATED Chemical Slurry						
Bentonite Id: 10	% ACETONE IN DEIONIZED WATER						
INDICATOR TEST	5	15	25	R_1	R_2	50	75*
A. MARSH FUNNEL VISCOSITY (sec)	43.1	51.1	75.4	80.0	68.0	27.8	31.9
B. GEL STRENGTH (lb/100 ft^2)							
- 10 sec	3.0	2.0	4.0	4.0	4.0	37.0	0.0
- 10 min	4.0	4.0	16.0	17.0	14.0	101.0	0.5
C. APPARENT VISCOSITY (cP)	25.5	26.0	37.0	40.0	37.0	70.0	0.5
D. YIELD POINT (lb/100 ft^2)	13.0	17.0	22.0	28.0	22.0	64.0	0.0
E. PLASTIC VISCOSITY (cP)	18.0	20.0	26.0	26.0	26.0	38.0	5.0
F. FREE SWELL - 2 hr.	--	--	--	--	--	--	--
- 24 hr.	--	--	--	--	--	--	--
G. MUD WEIGHT (pcf)	64.0	63.5	62.7	62.8	62.5	60.5	56.0
H. SPECIFIC CONDUCTANCE (mmhos)	.642	.515	.443	.442	.438	.340	.0643
J. API FILTRATE LOSS							
(ml)	9.0	8.0	6.8	6.5	7.0	6.8	24.4
cake thickness [mm]	[1.8]	[1.2]	[1.3]	[1.2]	[1.4]	[2.7]	[5.7]
(ml/mm)	5.0	6.7	5.2	5.4	5.0	2.5	4.3
K. pH	9.3	9.4	9.4	9.5	9.5	9.4	8.8
Slurry Temperature (°C)	20.7	20.7	20.8	20.8	20.6	22.4	23.0
RUN:	9	10	11	12	13	14	15

NOTE: "Outlier" results in parentheses ( )
Slurry remixed immediately prior to test
*A paste of lower moisture content was used to prepare the 75% slurry

TABLE A-21. PRIMARY TEST RESULTS (phase II) MODIFIED SWELL

Type: UNALTERED	CHEMICAL				
Bentonite Id: 1 (Lot 2)	WATER	R1	ACETONE	METHANOL	XYLENE
ELAPSED TIME (hours)					
1	.0239	.02505	.02183	.052	.00822
2	.0359	.03705	.03733	.0751	.01722
3	.0434	.04408	.04888	.09505	.02444
4	.04975	.0498	.05798	.1111	.03082
5	.05358	.05555	.06643	.12355	.03602
6	.0574	.0603	.07388	.13520	.04077
7	.0594	.0638	.08028	.149	.04505

NOTE: All data cumulative swell in inches

TABLE A-22. PRIMARY INDICATOR TEST RESULTS (phase II) MODIFIED SWELL

Type: POLYMER PROTECTED	CHEMICAL				
Bentonite Id: 3 (Lot 2)	WATER	R1	ACETONE	METHANOL	XYLENE
ELAPSED TIME (hours)					
1	.0617	.06023	.01492	.04155	.04963
2	.0902	.08708	.0283	.0631	.07403
3	.11295	.10768	.04195	.079	.09228
4	.1316	.12568	.0527	.0923	.10778
5	.1479	.14213	.0621	.104	.12223
6	.1647	.15818	.06965	.115	.13493
7	.17525	.16958	.07765	.12568	.14628

NOTE: All data cumulative swell in inches

TABLE A-23. PRIMARY INDICATOR TEST RESULTS (phase II) MODIFIED SWELL

Type: PHYSICALLY ALTERED	CHEMICAL				
Bentonite Id: 9 (Lot 2)	WATER	R1	ACETONE	METHANOL	XYLENE
ELAPSED TIME (hours)					
1	.0252	.02645	.0236	.02055	.02212
2	.0363	.0371	.03125	.02685	.02978
3	.044	.0437	.0373	.03145	.03535
4	.0487	.04902	.0423	.03565	.04008
5	.0532	.0534	.04585	.03955	.0436
6	.0573	.05708	.0492	.04275	.04668
7	.0611	.067	.05228	.0452	.0494

NOTE: All data cumulative swell in inches

TABLE A-24. PRIMARY INDICATOR TEST RESULTS (phaseII) MODIFIED SWELL

Type: CHEMICALLY TREATED	CHEMICAL				
Bentonite Id: 6 (Lot 2)	WATER	R1	ACETONE	METHANOL	XYLENE
ELAPSED TIME (hours)					
1	.03675	.03233	.0253	.01615	.02847
2	.05075	.04778	.0348	.02915	.04482
3	.062	.05873	.0422	.038	.05652
4	.0701	.06808	.0468	.04505	.06522
5	.07735	.07598	.051	.05170	.07357
6	.08398	.08326	.0552	.057	.08027
7	.0899	.08958	.0588	.0617	.08662

NOTE: All data cumulative swell in inches

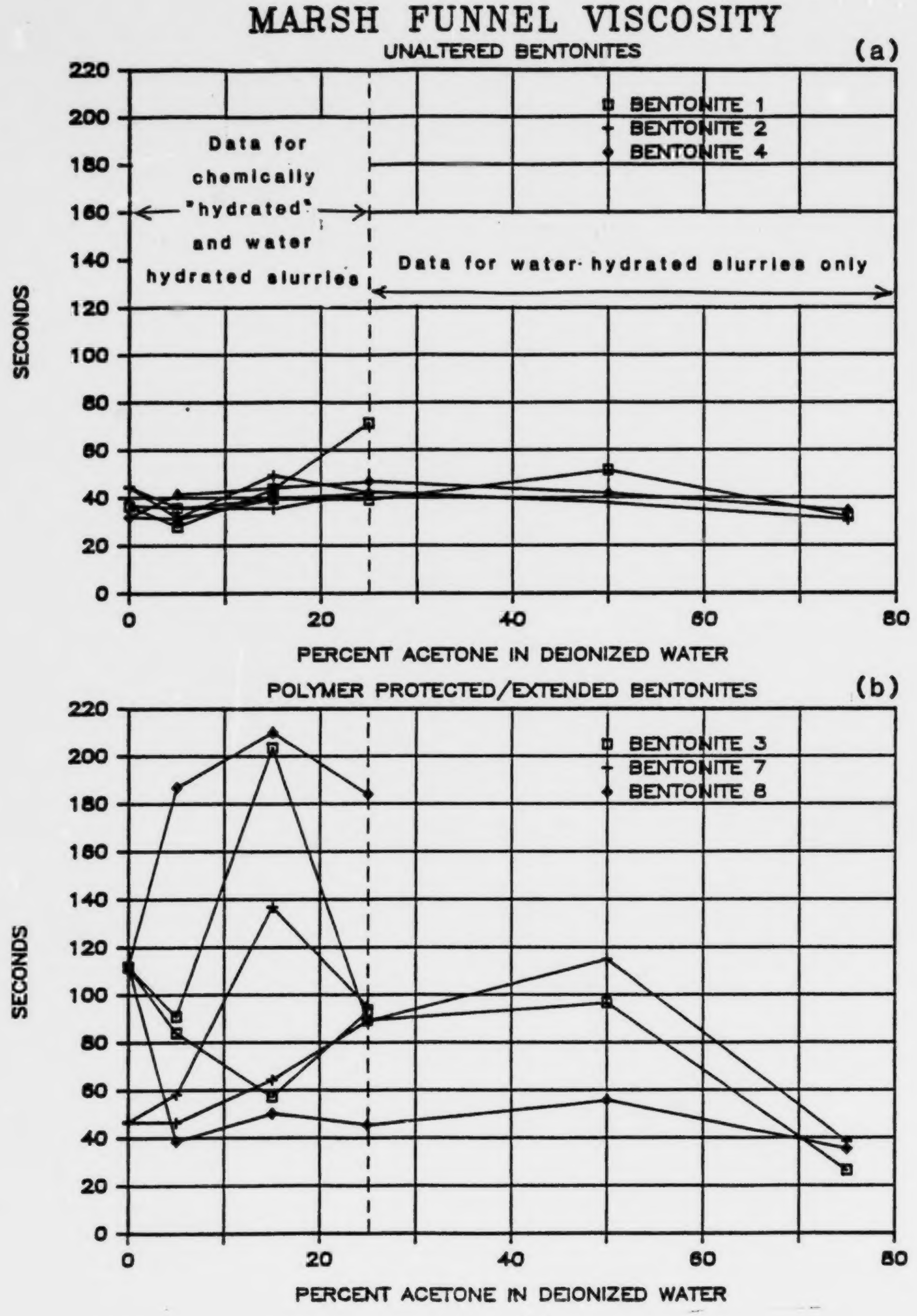


Figure A-1: Selected Phase II primary indicator test results for Marsh Funnel Viscosity test.

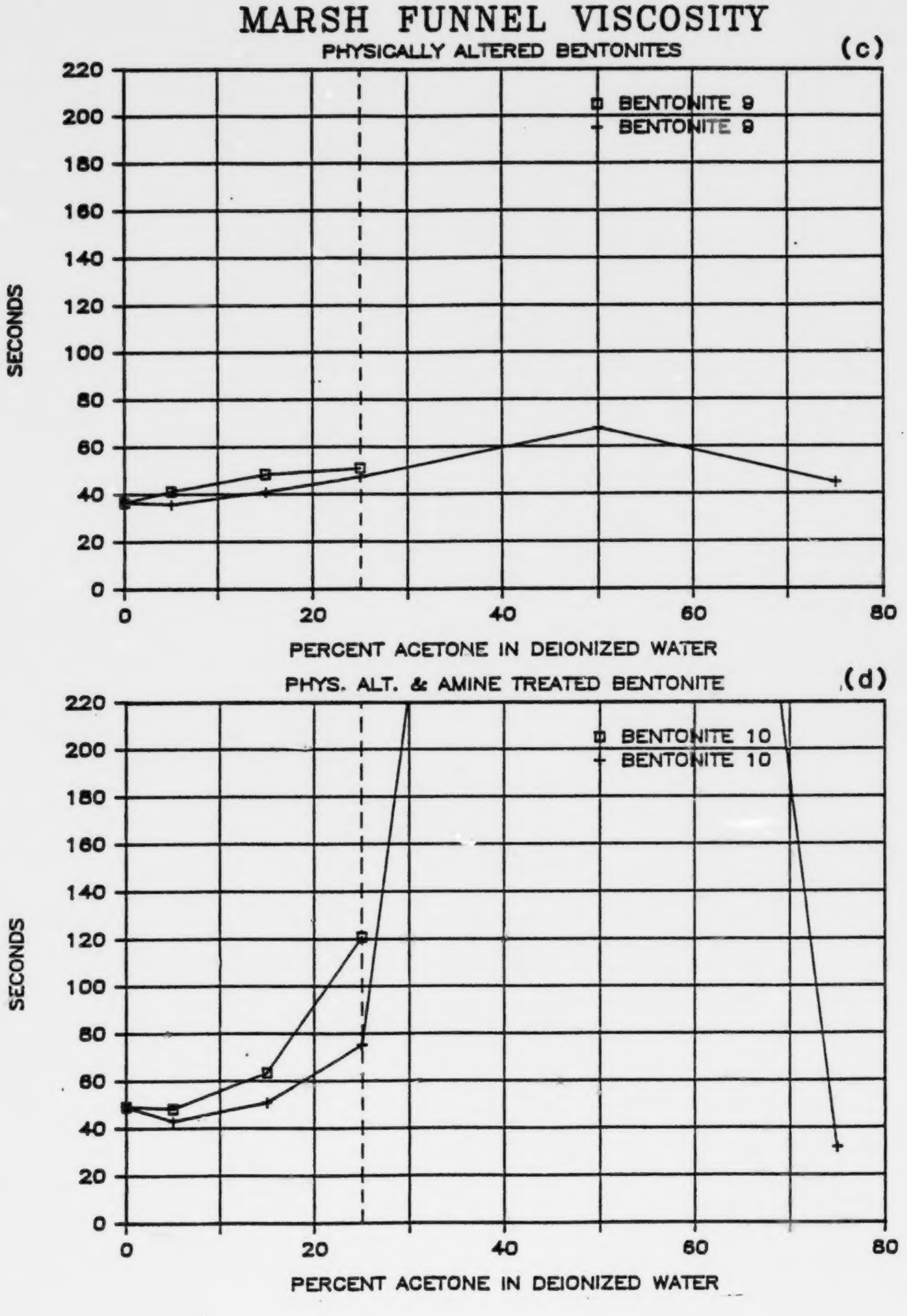


Figure A-1: (continued)

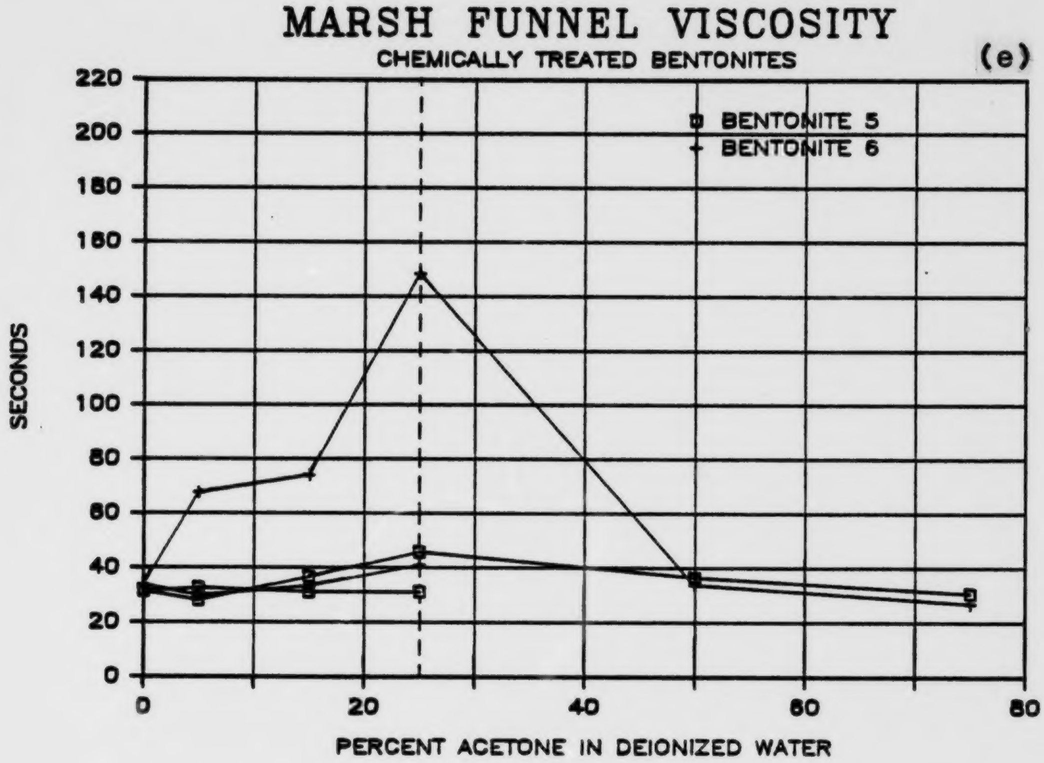


Figure A-1: (continued)

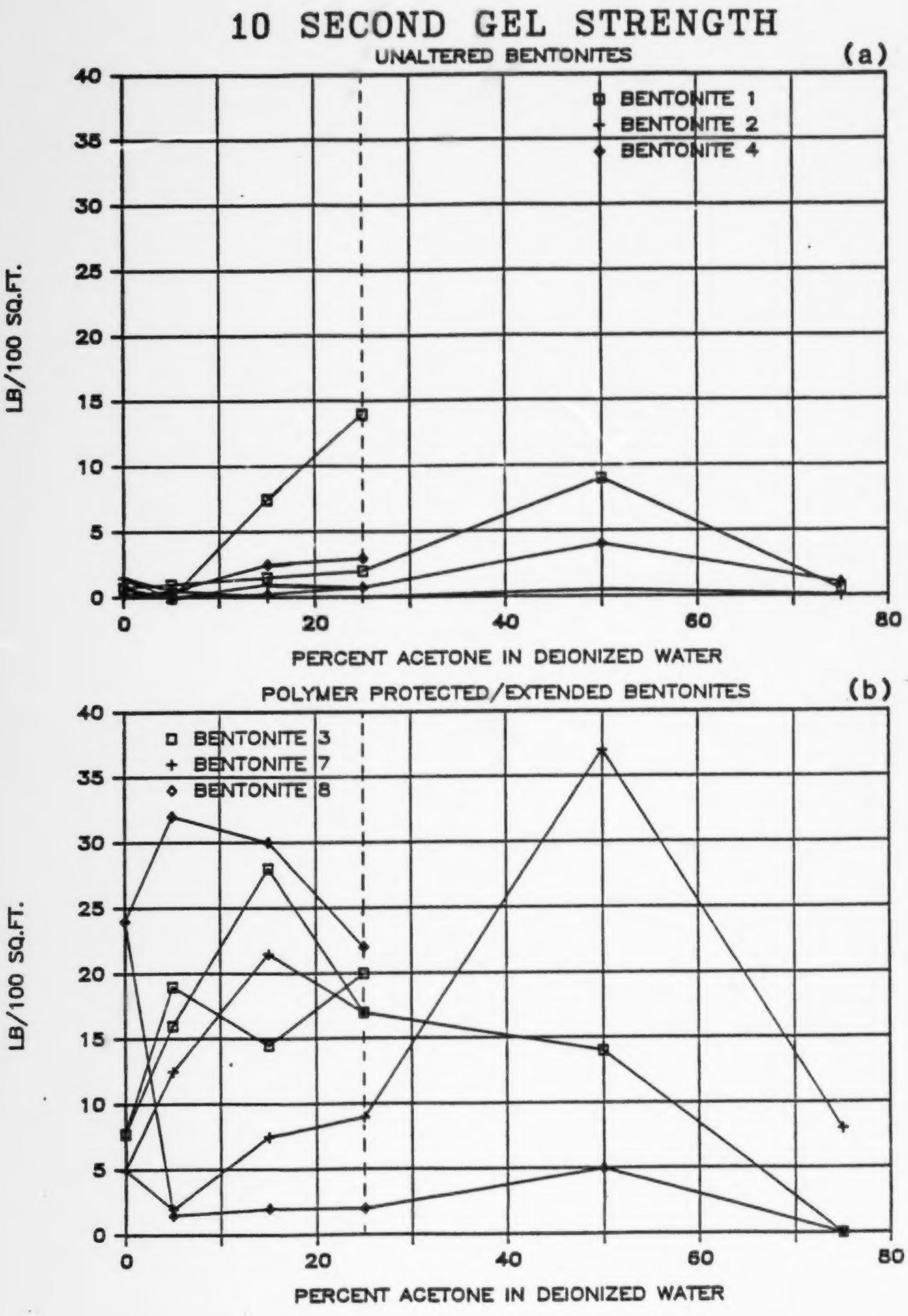


Figure A-2: Selected Phase II primary indicator test results for 10 Second Gel Strength test.

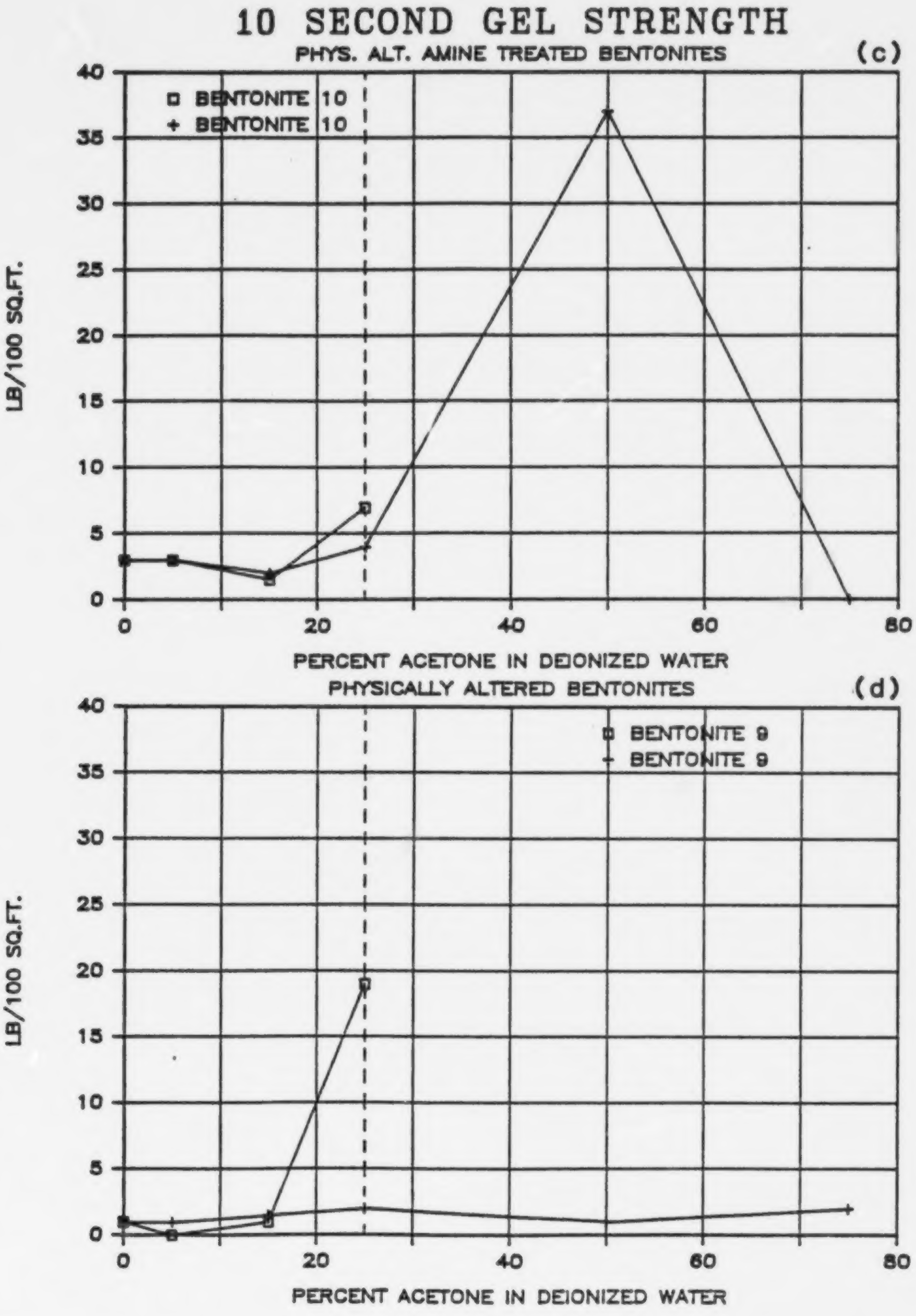


Figure A-2: (continued)

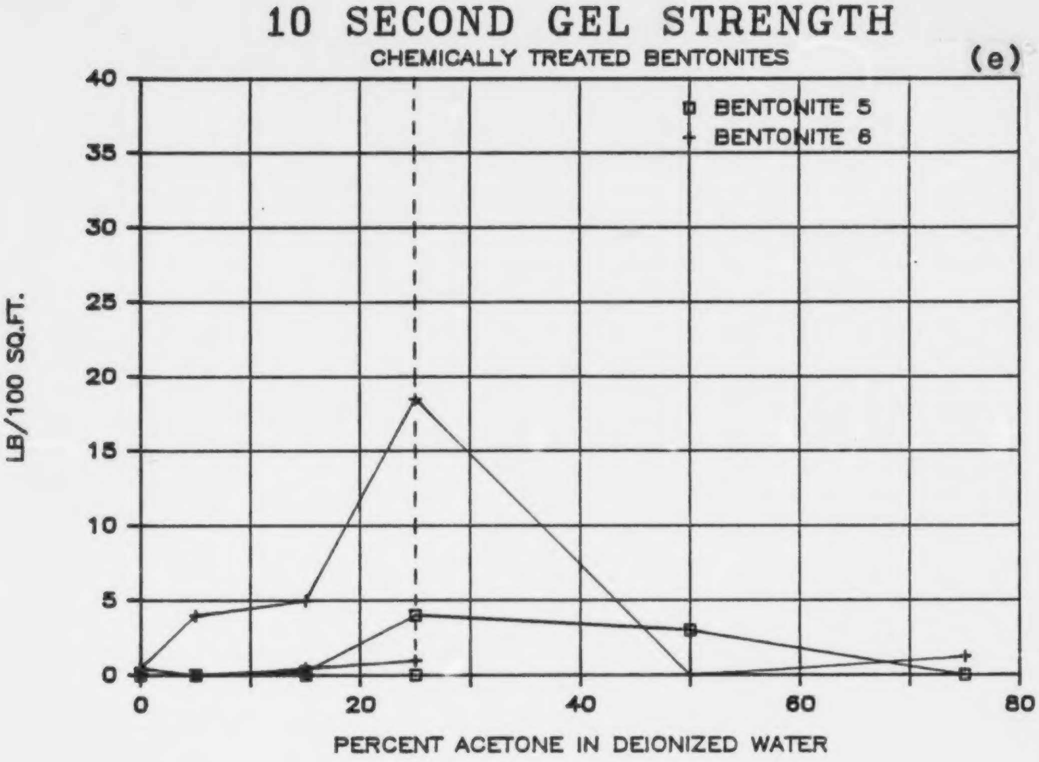


Figure A-2: (continued)

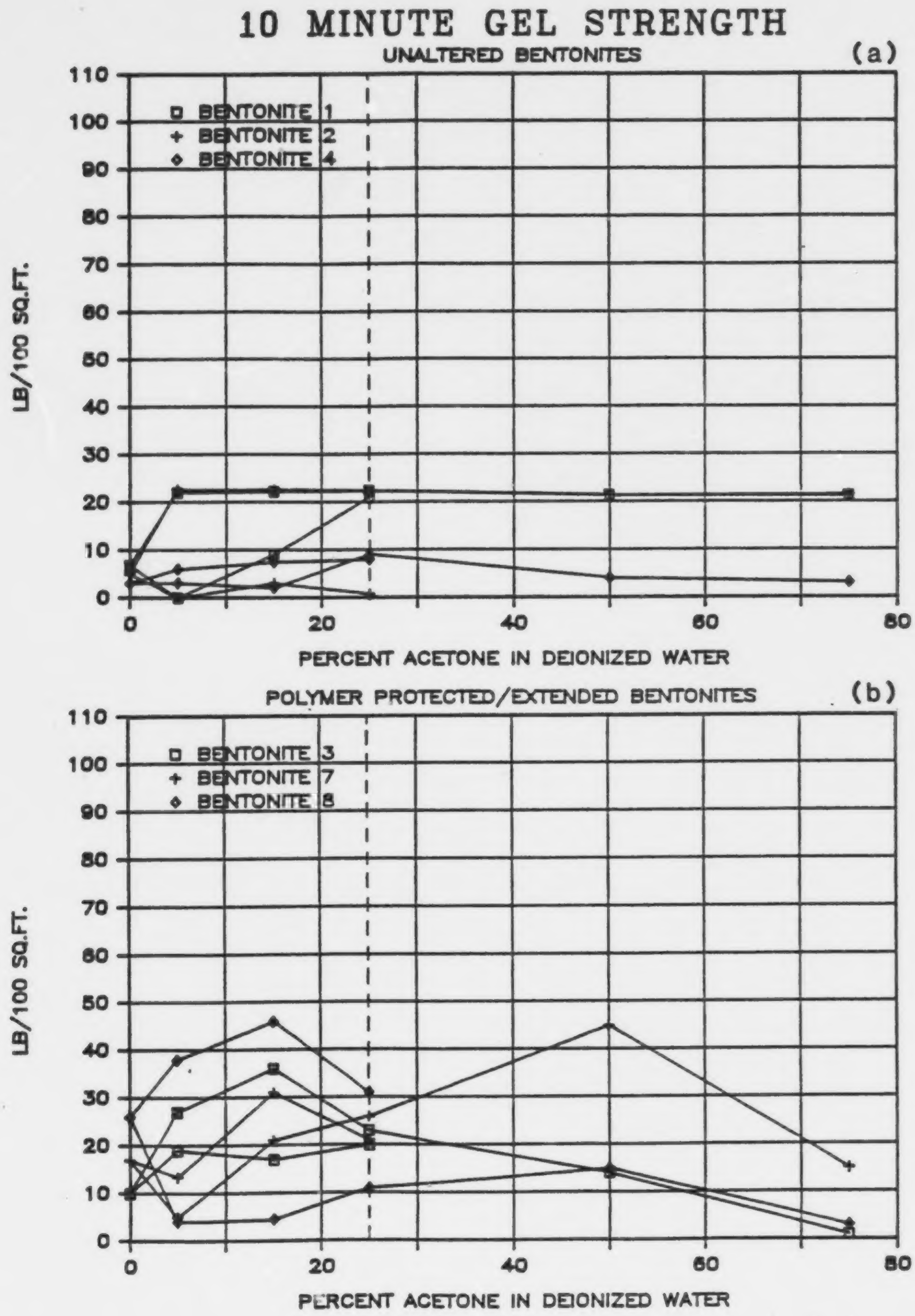


Figure A-3: Selected Phase II primary indicator test results for 10 Minute Gel Strength test.

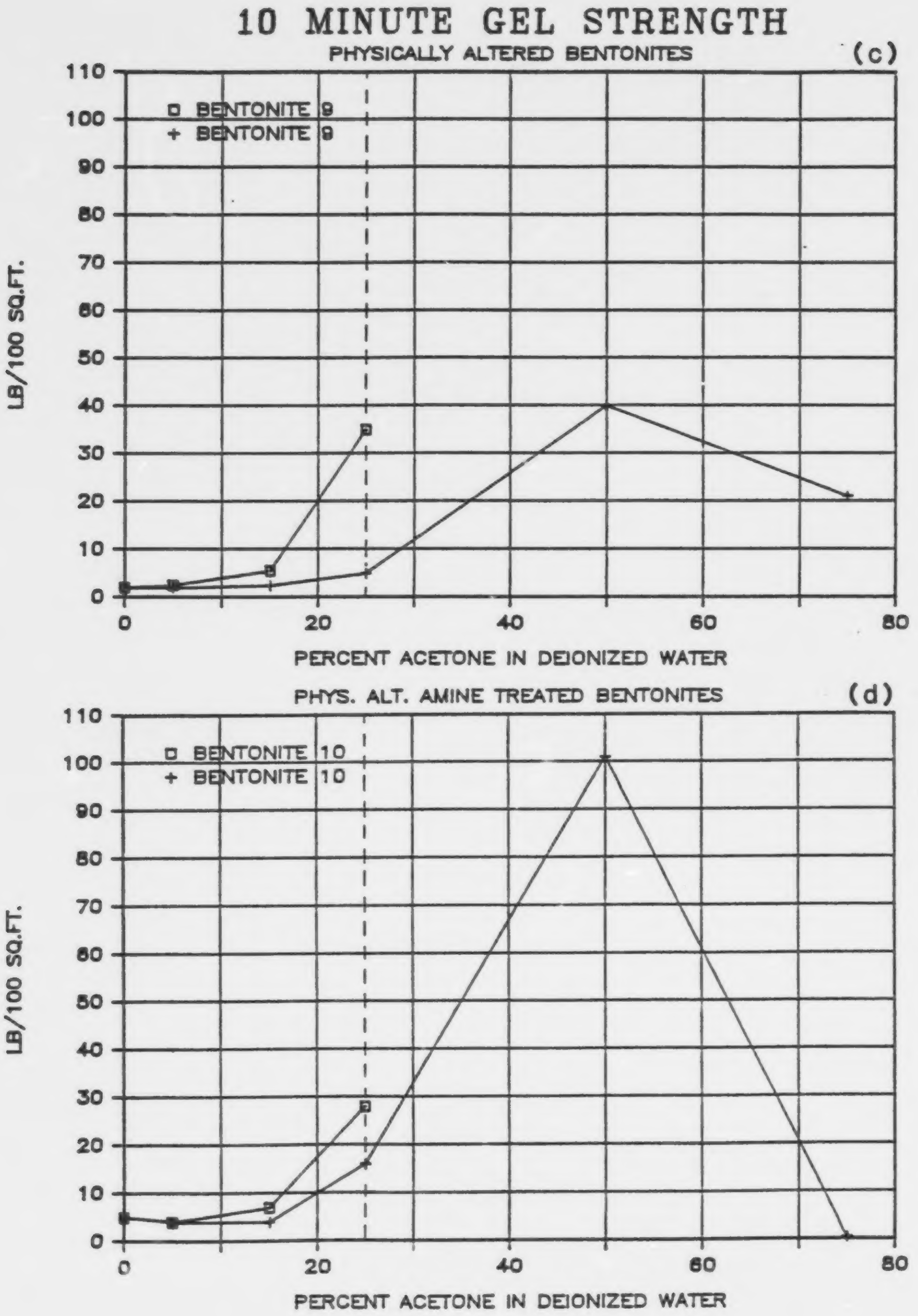


Figure A-3: (continued)

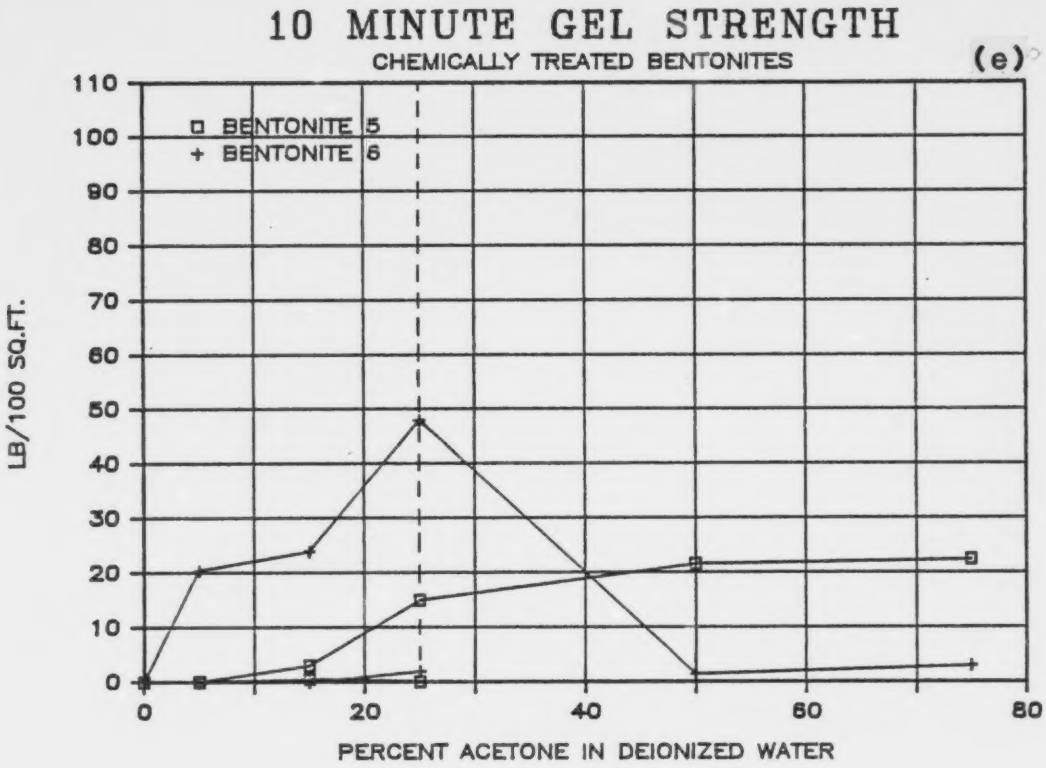
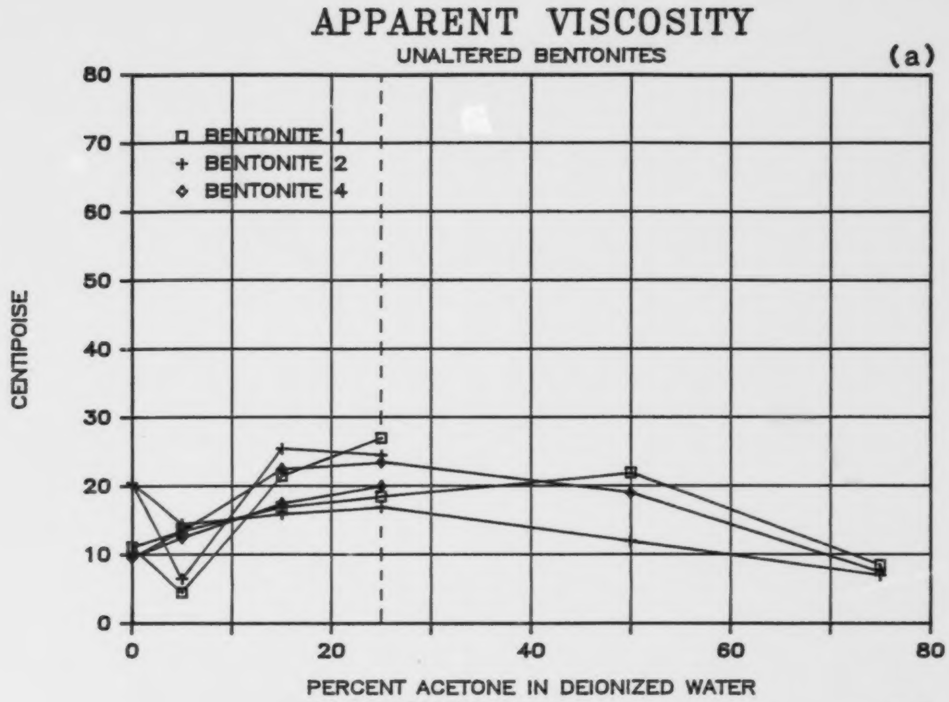


Figure A-3: (continued)



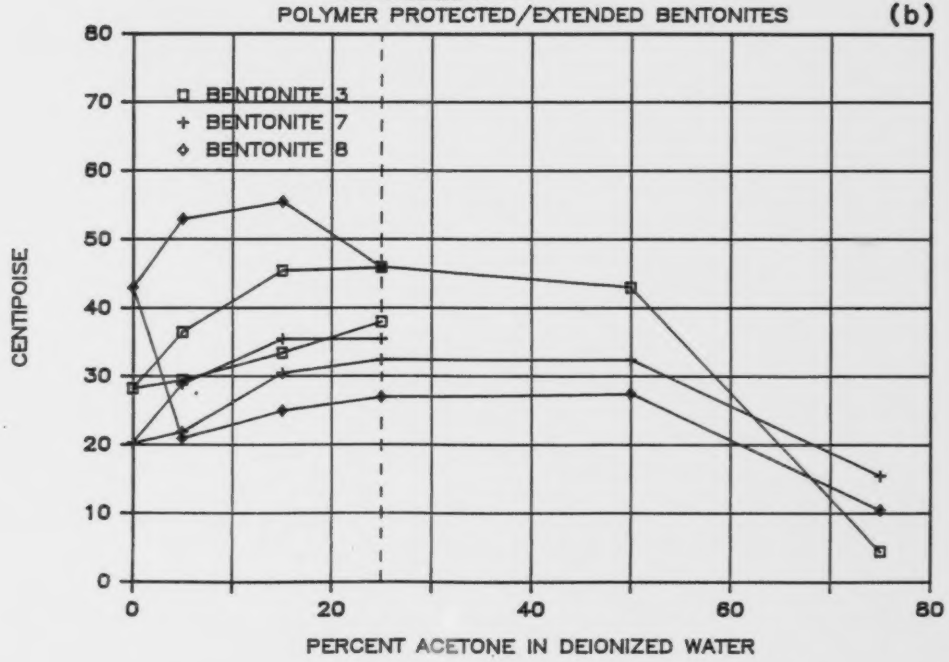
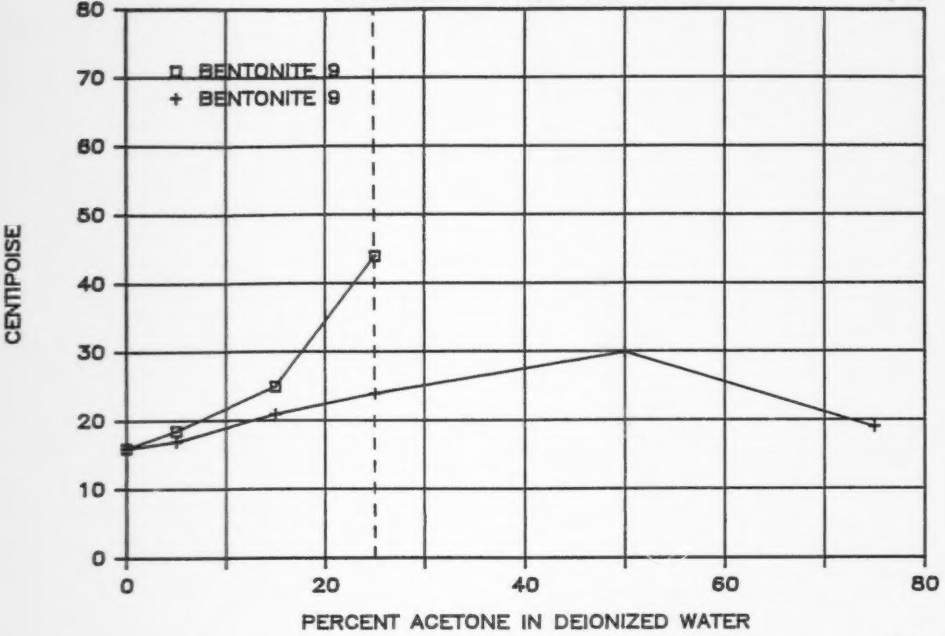


Figure A-4: Selected Phase II primary indicator test results for Apparent Viscosity test.

APPARENT VISCOSITY

PHYSICALLY ALTERED BENTONITES (c)



PHYS. ALT. AMINE TREATED BENTONITES (d)

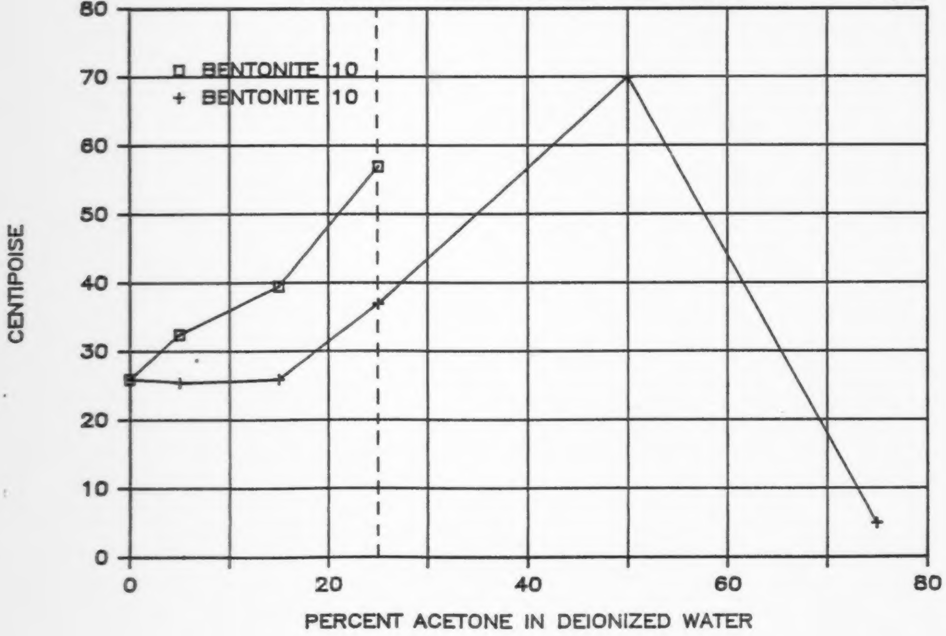
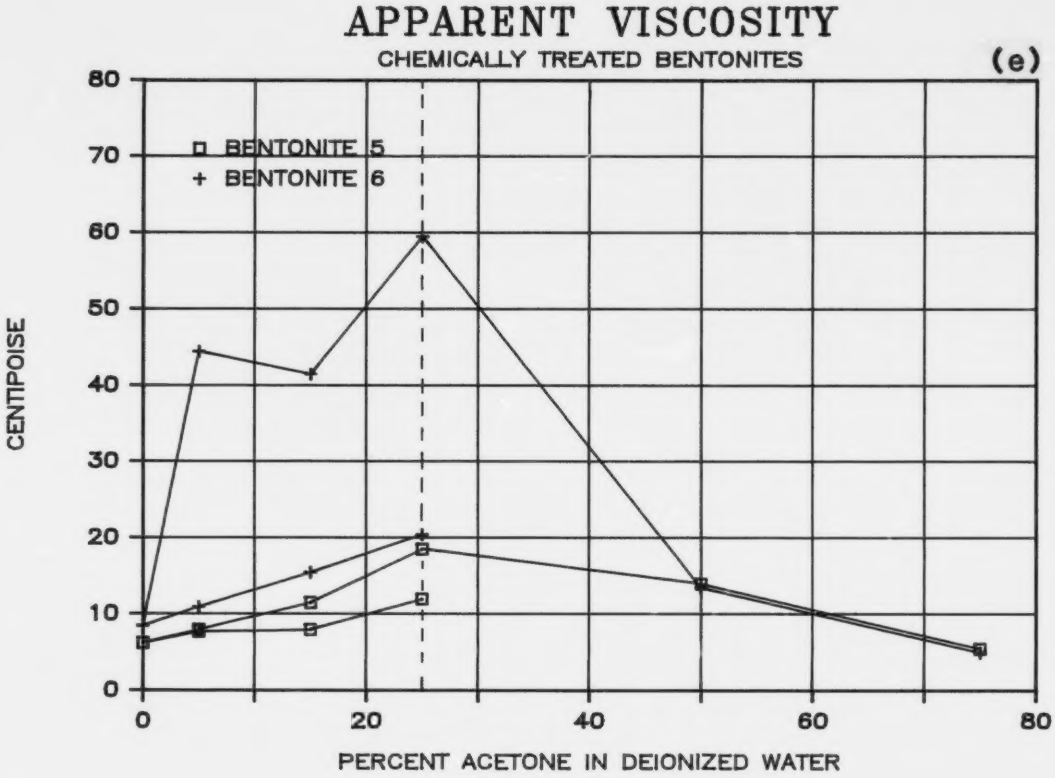


Figure A-4: (continued)



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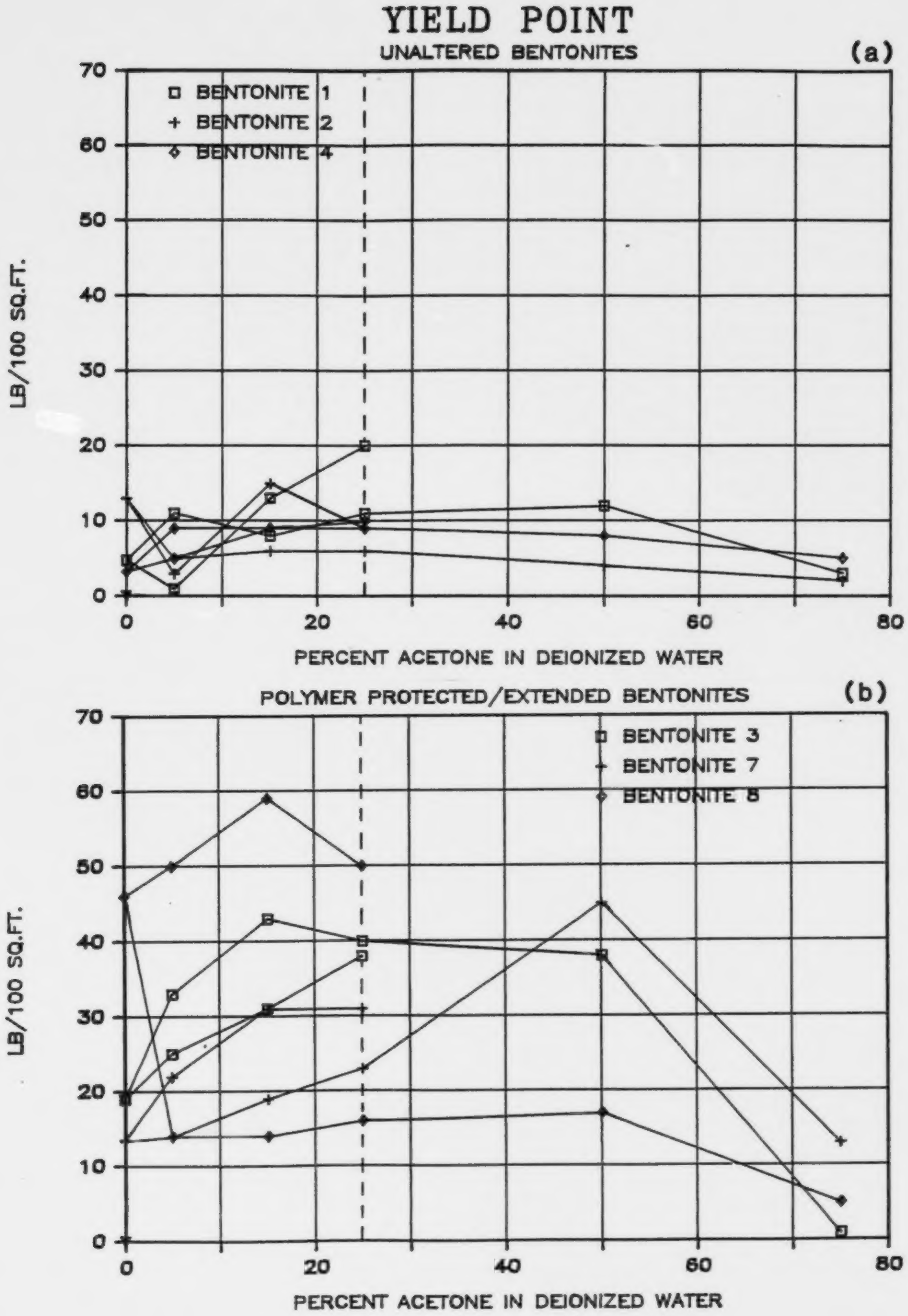


Figure A-5: Selected Phase II primary indicator test results for Yield Point test.

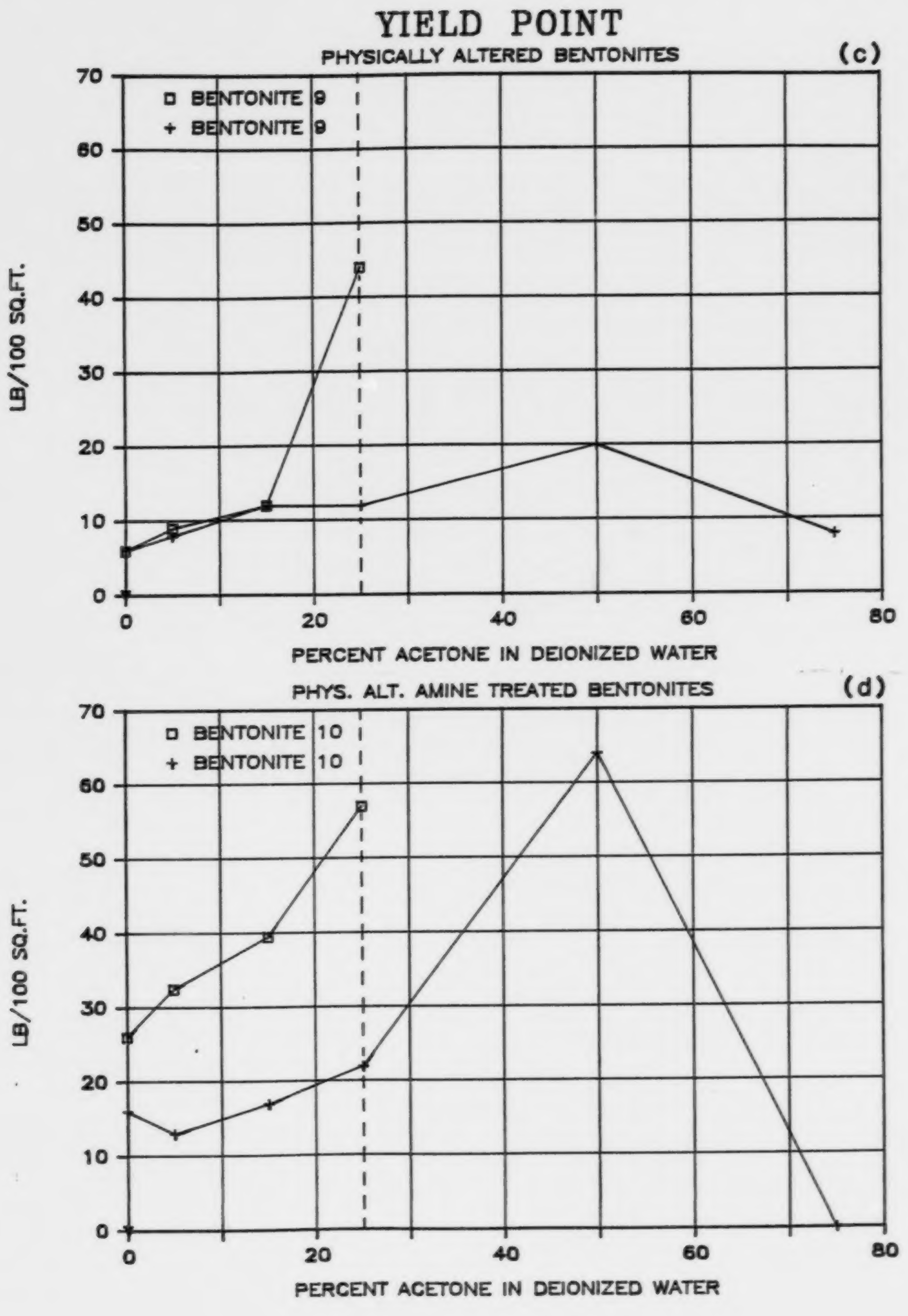


Figure A-5: (continued)

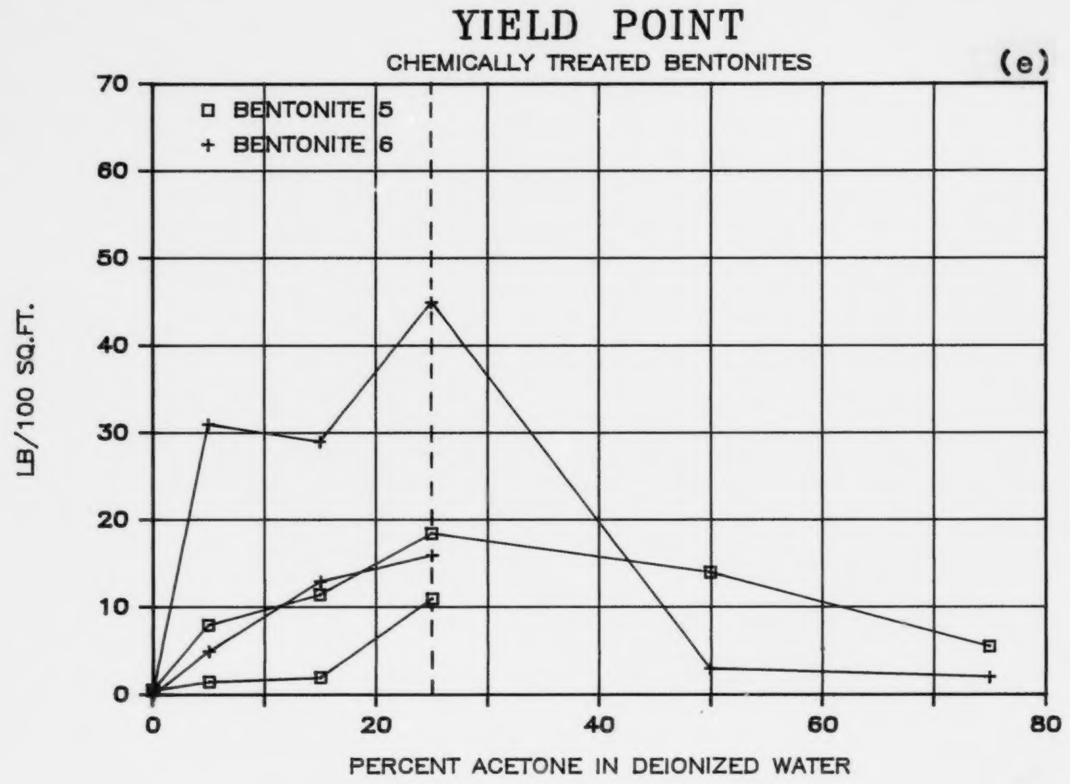
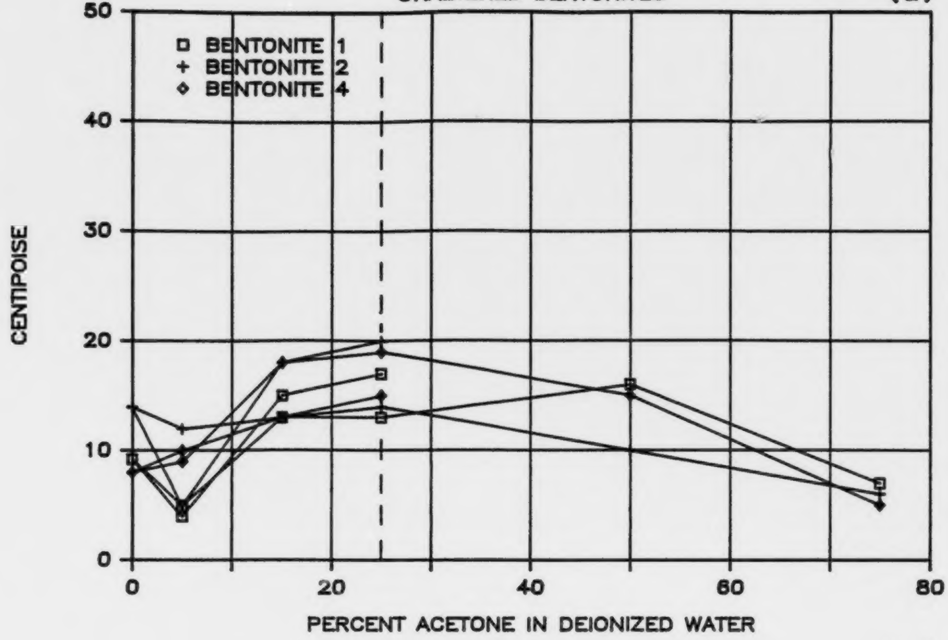


Figure A-5: (continued)

PLASTIC VISCOSITY

UNALTERED BENTONITES (a)



POLYMER PROTECTED/EXTENDED BENTONITES (b)

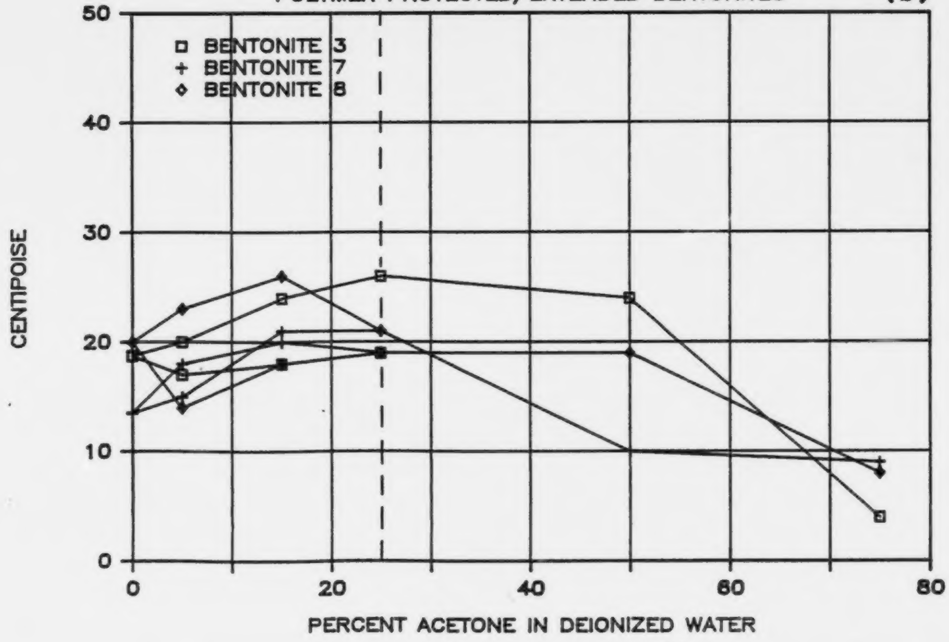
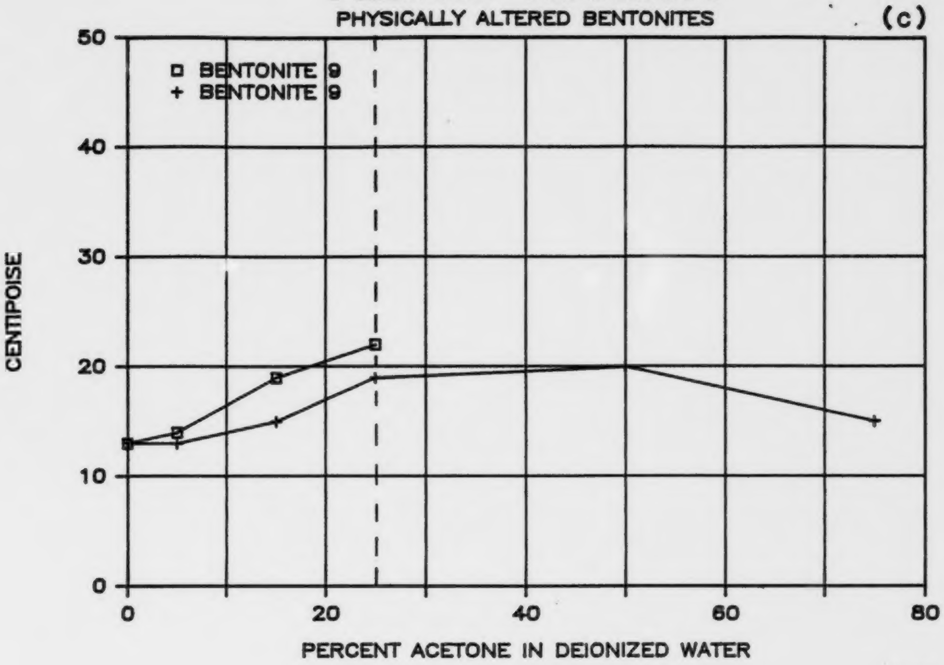


Figure A-6: Selected Phase II primary indicator test results for Plastic Viscosity test.

PLASTIC VISCOSITY



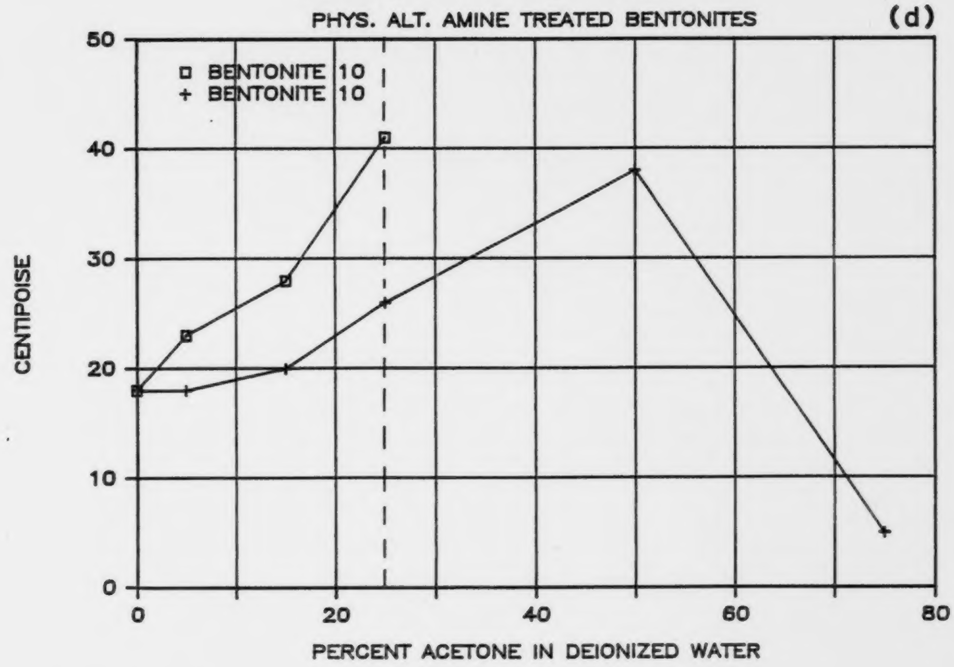


Figure A-6: (continued)

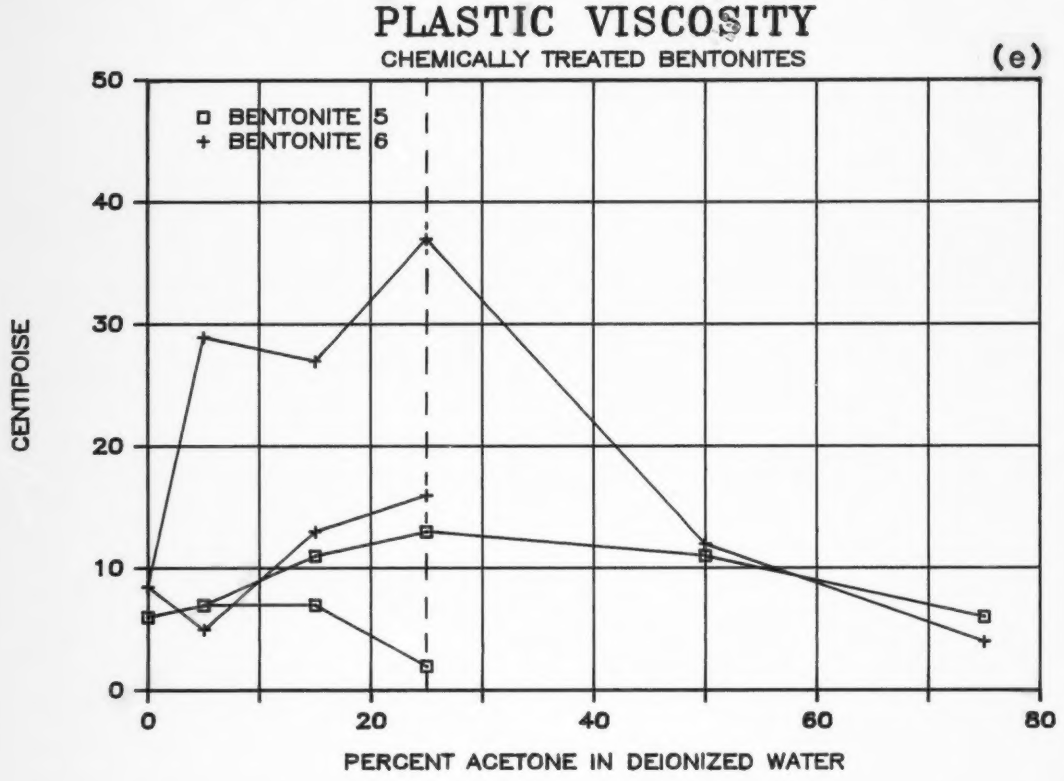


Figure A-6: (continued)

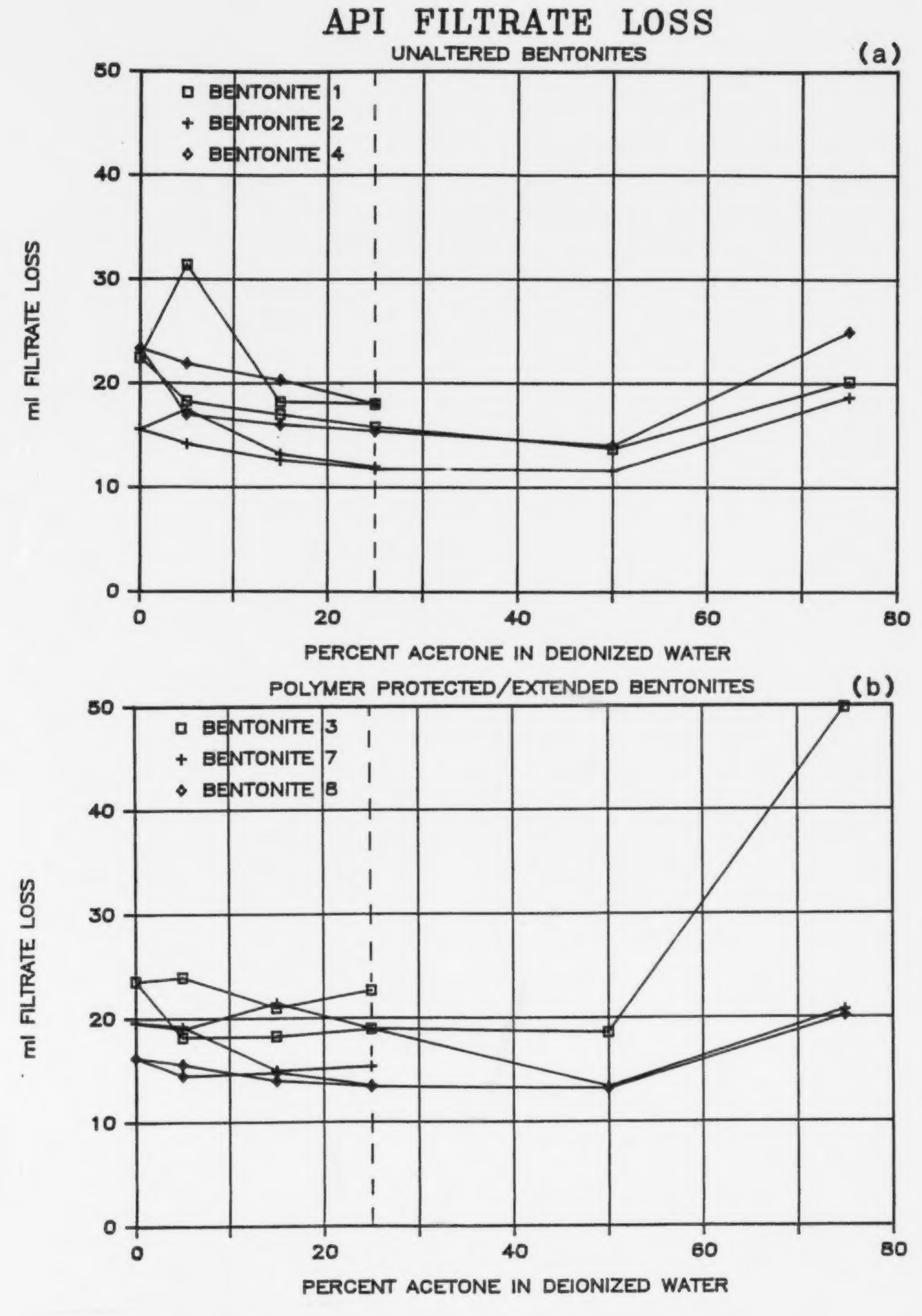
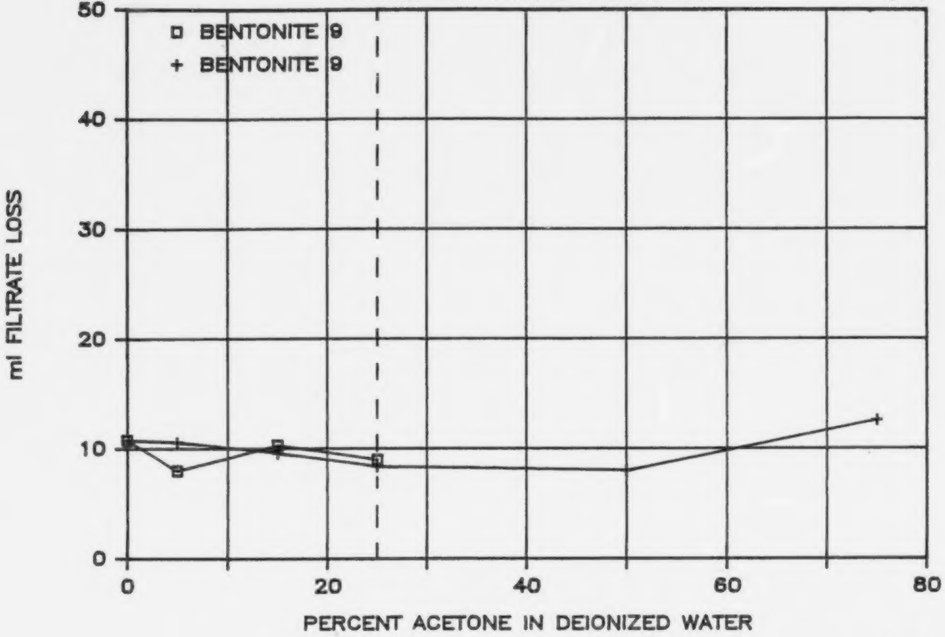


Figure A-7: Selected Phase II primary indicator test results for API Filtrate Loss test.

API FILTRATE LOSS

PHYSICALLY ALTERED BENTONITE (c)



PHYS. ALT. AMINE TREATED BENTONITE (d)

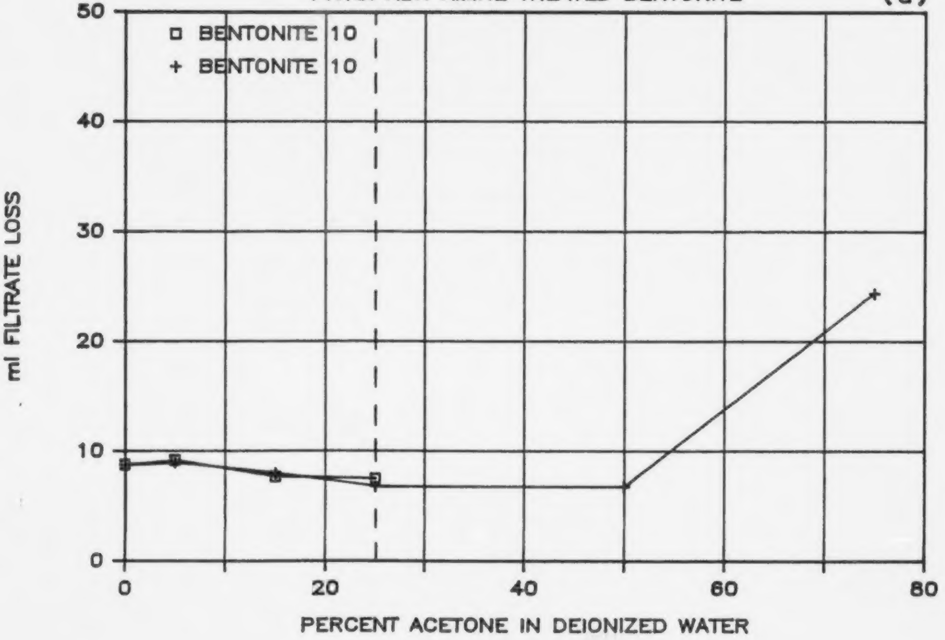


Figure A-7: (continued)

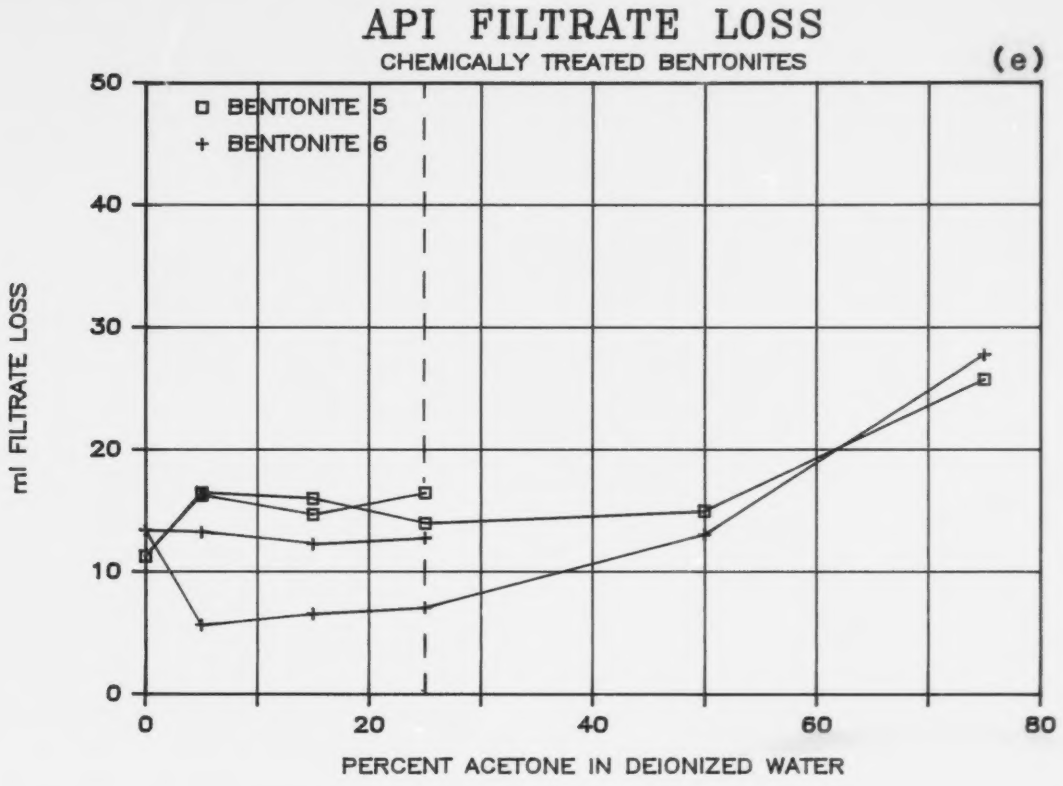


Figure A-7: (continued)

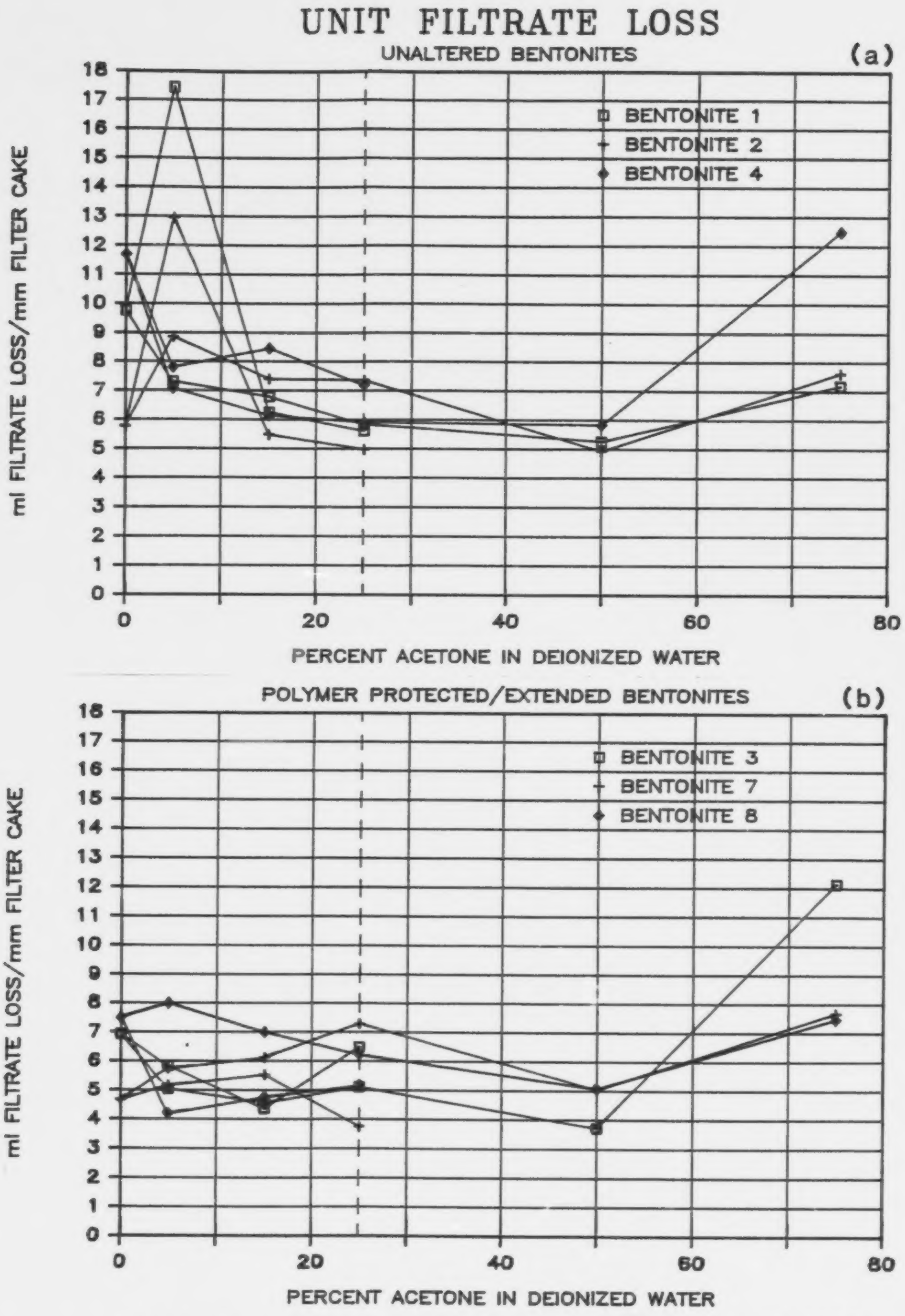
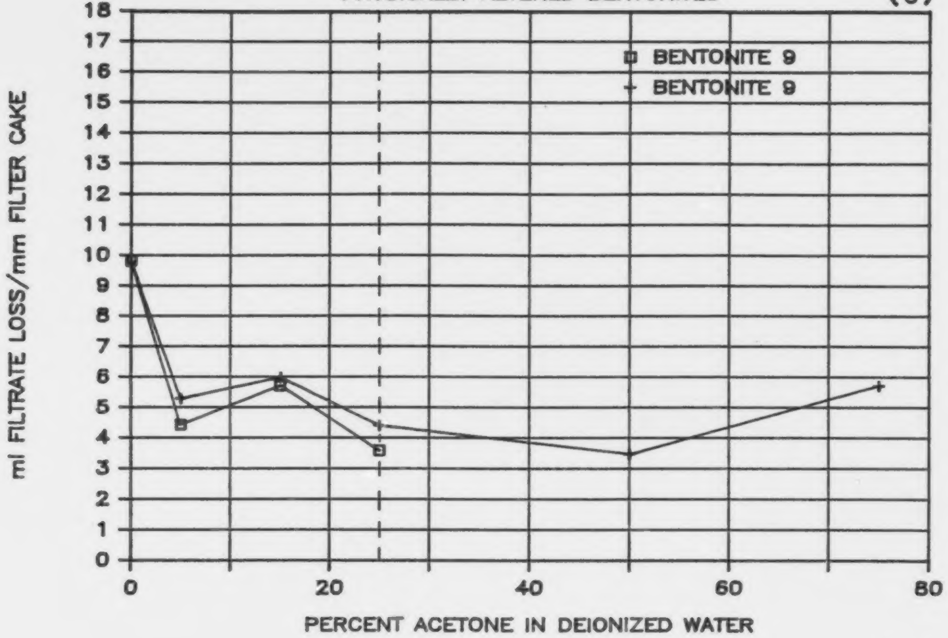


Figure A-8: Selected Phase II primary indicator test results for Unit Filtrate Loss test.

UNIT FILTRATE LOSS


PHYSICALLY ALTERED BENTONITES (c)

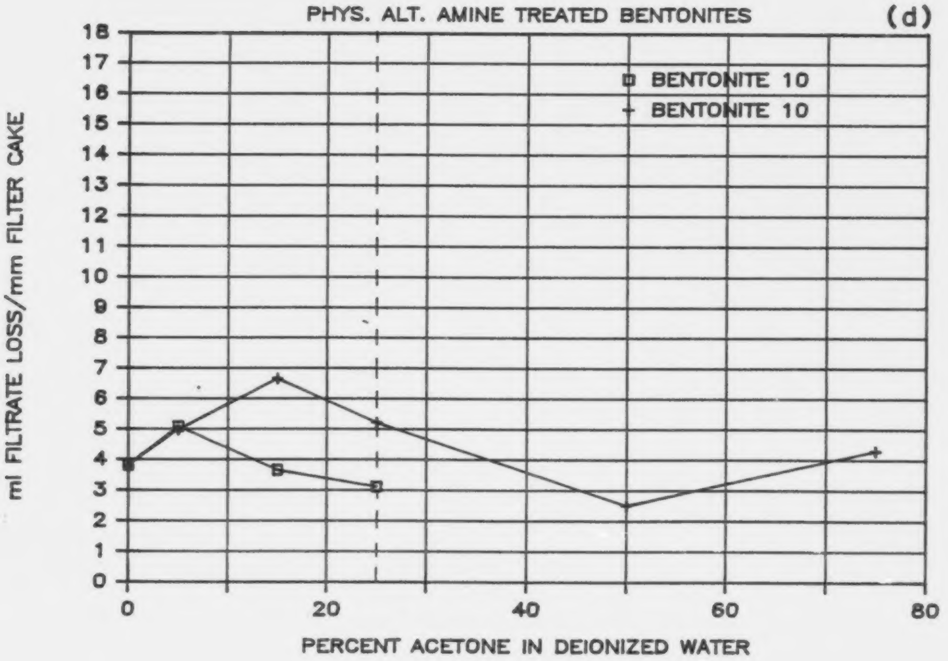

PHYS. ALT. AMINE TREATED BENTONITES (d)

Figure A-8: (continued)

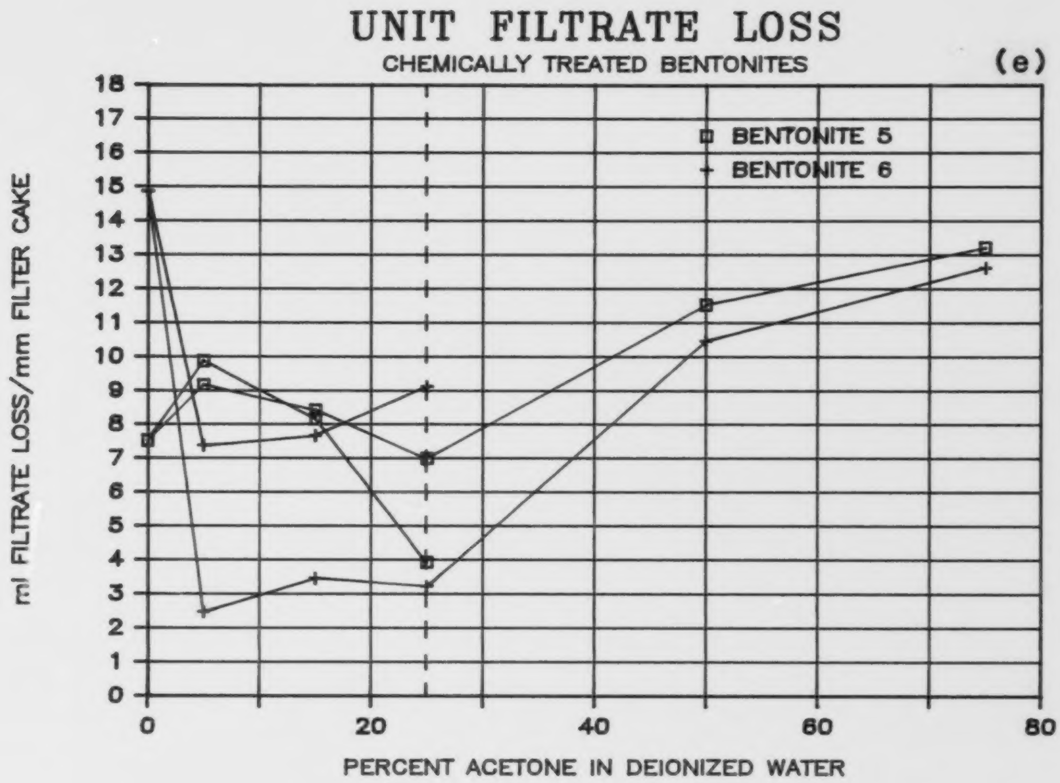


Figure A-8: (continued)

TABLE A-25. STATISTICAL PARAMETERS - MARSH FUNNEL VISCOSITY TEST

		PRIMARY TESTS WITH REPLICATION*						ANALYST** PROFICIENCY
Bentonite Id.		1	3	7	9	10	5	2
Type		A Unalt	B Poly Prot(or)	B Poly Ext	C Phys Alt	D Phys Alt-AT	E Chem Trtd	Unalt
No. of Reps		3	(3) 2	3	3	(3) 2	3	4
BASELINE Slurry (0% Acetone)	$\overline{x}$	35.6	(94.0) 111.2	44.2	37.0	47.0	31.2	42.8
	RR	9.6	(55.7) 1.4	10.9	10.3	7.7	8.7	18.7
	σ	2.0	(29.8) 1.1	2.5	1.9	1.9	1.4	3.4
	CV	5.6	(31.7) 1.0	5.7	5.2	4.1	4.5	8.0
CHEMICALLY HYDRATED Slurry (25% Acetone)	x	67.6	94.3	107.7	52.0	(132.7) 118.4	34.9	--
	RR	9.2	18.9	22.3	3.7	(34.2) 4 2	16.9	
	σ	3.4	9.0	12.0	1.0	(24.9) 3 5	3.2	--
	CV	5.0	9.5	11.1	1.8	(18.8) 3.0	9.1	--
WATER HYDRATED CHEMICAL Slurry (25% Acetone)	$\overline{x}$	43.1	98.7	78.3	46.7	74.5	42.6	--
	RR	18.6	17.8	21.3	13.3	16.1	23.0	
	σ	4.0	8.8	9.4	3.2	6.1	5.7	--
	CV	9.3	8.9	12.0	6.8	8.1	13.3	--

(continued)

TABLE A-25 (continued)

Bentonite Id.		1,2,4	3,7,8	9	10	5,6	
		ALL PRIMARY TEST RESULTS*** (NO REPLICATES)					
Type		A Unalt	B Poly Prot or Ext	C Phys Alt	D Phys Alt-AT	E Chem Trtd	ALL ALL
BASELINE Slurry (0% Acetone)	$\bar{x}$	37.8	90.5	[36.7]	[49.2]	32.9	53.6
	RR	35.6	72.5	--	--	7.0	150.6
	σ	6.4	37.7	--	--	--	31.5
	CV	16.9	41.7	--	--	--	58.8
CHEMICALLY HYDRATED Slurry (25% Acetone)	$\bar{x}$	52.0	124.1	[51.0]	[120.9]	36.3	77.3
	RR	56.5	73.3	--	--	27.3	
	σ	16.9	51.9	--	--	--	47.7
	CV	--	--	--	--	--	--
		32.5	41.8				61.7
WATER HYDRATED CHEMICAL Slurry (25% Acetone)	$\bar{x}$	43.2	74.7	[47.4]	[75.4]	97.3	67.1
	RR	17.8	58.9			105.6	
	σ	4.2	25.3	--	--	--	34.6
	CV	9.7	33.9	--	--	--	51.6

* Includes operator and batching variability
** Operator variability; may include type variability for unaltered bentonites
*** Includes operator, type, and batching variability

Values in parentheses ( ) include "outlier" results
Values in brackets [ ] represent single sample

TABLE A-26. STATISTICAL PARAMETERS - 10-SECOND GEL STRENGTH TEST

		PRIMARY TESTS WITH REPLICATION*						ANALYST** PROFICIENCY
Bentonite Id.		1	3	7	9	10	5	2
Type		A Unalt	B Poly Prot(or)	B Poly Ext	C Phys Alt	D Phys Alt-AT	E Chem Trtd	A Unalt
No. of Reps		3	(3) 2	3	3 2	(3) 2	3	3
BASELINE Slurry (0% Acetone)	$\bar{x}$	0.75	(6.6) 7.4	4.33	0.75	1.67	0.033	1.0
	RR	66.67	(41.8) 10.2	46.2	66.67	180	300	0.0
	σ	0.25	(1.4) 0.53	1.16	0.25	1.53	0.058	0.0
	CV	33.3	(21.2) 7.2	26.6	33.3	91.7	173.2	0.0
CHEMICALLY HYDRATED Slurry (25% Acetone)	$\bar{x}$	12.33	20.33	18.33	(14.33) 20.00	5.33	0.0	
	RR	24.3	4.9	16.4	(125.6) 10.00	56.25	0.0	
	σ	1.53	0.6	1.53	(9.9) 1.4	1.53	0.0	
	CV	12.4	2.8	8.3	(68.8) 7.1	28.6	0.0	
WATER HYDRATED CHEMICAL Slurry (25% Acetone)	$\bar{x}$	3.33	18.67	9.0	1.4	4.0	4.33	
	RR	90.1	16.1	22.2	70.6	0.0	23.1	
	σ	1.53	1.53	1.0	0.52	0.0	0.58	
	CV	45.8	8.2	11.1	36.7	0.0	13.3	

(Continued)

TABLE A-26 (continued)

		ALL PRIMARY TEST RESULTS*** (NO REPLICATES)					
Bentonite Id.		1,2,4	3,7,8	9	10	5,6	ALL
Type		A Unalt	B Poly Prot or Ext	C Phys Alt	D Phys Alt-AT	E Chem Trtd	ALL
BASELINE Slurry (0% Acetone)	$\bar{x}$	0.83	12.25	[1.0]	[3]	0.25	4.4
	RR	150	155.1	--	--	200	177.1
	σ	0.63	10.3	--	--	--	7.3
	CV	75.5	83.8	--	--	--	167.4
CHEMICALLY HYDRATED Slurry (25% Acetone)	$\bar{x}$	5.9	25.67	[19]	[7]	0.5	10.4
	RR	223.9	81.8	--	--	200	212.0
	σ	7.1	11.0	--	--	--	8.9
	CV	119.8	42.7	--	--	--	85.8
WATER HYDRATED CHEMICAL Slurry (25% Acetone)	$\bar{x}$	6.4	9.33	[2]	[4]	18.5	5.9
	RR	288.3	160.7	--	--	0.0	313.6
	σ	10.5	7.5	--	--	--	6.7
	CV	163.2	80.4	--	--	--	113.3

* Includes operator and batching variability

** Operator variability; may include type variability for unaltered bentonites

*** Includes operator, type, and batching variability

Values in parentheses ( ) include "outlier" results
Values in brackets [ ] represent single sample

TABLE A-27. STATISTICAL PARAMETERS - 10-MINUTE GEL STRENGTH TEST

		PRIMARY TESTS WITH REPLICATION*						ANALYST** PROFICIENCY
Bentonite Id.		1	3	7	9	10	5	2
Type		A Unalt	B Poly Prot(or)	B Poly Ext	C Phys Alt	D Phys Alt-AT	E Chem Trtd	A Unalt
No. of Reps		(3) 2	3	3	(3) 2	3	3	
BASELINE Slurry (0% Acetone)	$\bar{x}$	6.6	11.5	17.0	1.8	3.33	0.067	4.0
	RR	75.9	21.7	0.0	27.3	90.0	300.0	0.0
	σ	2.5	1.3	0.0	0.3	1.5	0.12	0.0
	CV	38.0	11.5	0.0	15.7	45.8	173.2	0.0
CHEMICALLY HYDRATED Slurry (25% Acetone)	$\bar{x}$	22.33	20.33	22.0	(26.33) 35.5	30.67	0.0	--
	RR	13.4	4.9	9.1	2.8 (106.3)	19.6	--	--
	σ	1.5	0.6	1.0	(15.9) 0.71	3.1	0.0	--
	CV	6.8	2.8	4.5	(60.3) 2.0	10.0	--	--
WATER HYDRATED CHEMICAL Slurry (25% Acetone)	$\bar{x}$	(10.33) 14.5	27.0	27.0	7.0	15.67	13.8	--
	RR	6.9 (125.8)	25.9	7.4	42.9	19.1	21.7	--
	σ	(7.2) 0.7	3.6	1.0	1.7	1.5	1.6	--
	CV	(70.0) 4.9	13.4	3.7	24.7	9.8	11.6	--

(Continued)

TABLE A-27 (continued)

		ALL PRIMARY TEST RESULTS*** (NO REPLICATES)					
Bentonite Id.		1,2,4	3,7,8	9	10	5,6	ALL
Type		A Unalt	B Poly Prot or Ext	C Phys Alt	D Phys Alt-AT	E Chem Trtd	ALL
BASELINE Slurry (0% Acetone)	$\overline{x}$	4.9	17.67	[2]	[5]	0.0	7.5
	RR	76.3	90.6	--	--	0.0	347.3
	σ	1.9	8.0	--	--	--	8.3
	CV	38.2	45.4	--	--	--	110.6
CHEMICALLY HYDRATED Slurry (25% Acetone)	$\overline{x}$	9.9	24.0	[35]	[28]	1.0	16.7
	RR	204.2	45.8	--	--	100.0	209.9
	σ	10.3	6.1	--	--	--	13.1
	CV	103.5	25.3	--	--	--	78.4
WATER HYDRATED CHEMICAL Slurry (25% Acetone)	$\overline{x}$	8.0	23.3	[5]	[16]	31.5	16.8
	RR	162.5	64.5	--	--	104.8	279.8
	σ	6.6	2.61	--	--	--	13.3
	CV	82.0	11.2	--	--	--	79.2

* Includes operator and batching variability
** Operator variability; may include type variability for unaltered bentonites
*** Includes operator, type, and batching variability

Values in parentheses ( ) include "outlier" results
Values in brackets [ ] represent single sample

TABLE A-28. STATISTICAL PARAMETERS - APPARENT VISCOSITY TEST

		PRIMARY TESTS WITH REPLICATION*						ANALYST** PROFICIENCY
Bentonite Id.		1	3	7	9	10	5	2
Type		A Unalt	B Poly Prot(or)Poly Ext	B	C Phys Alt	D Phys Alt-AT	E Chem Trtd	A Unalt
No. of Reps		3	3	3	(3) 2	3	3	3
BASELINE Slurry (0% Acetone)	$\bar{x}$	11.0	28.4	20.1	15.6	25.6	6.25	22.67
	RR	9.1	0.9	2.5	8.0	10.7	8.0	2.2
	σ	0.5	0.1	0.3	0.7	1.4	0.25	0.3
	CV	4.6	0.5	1.4	4.6	5.6	4.0	1.3
CHEMICALLY HYDRATED Slurry (25% Acetone)	$\bar{x}$	27.33	39.8	34.5	(39.67) 44.5	53.8	12.0	
	RR	11.0	11.3	7.2	(37.8) 2.2	12.1	0.0	
	σ	0.6	2.4	1.3	(8.4) 0.7	3.25	0.0	
	CV	2.1	5.9	3.8	(21.1) 1.6	6.0	0.0	
WATER HYDRATED CHEMICAL Slurry (25% Acetone)	$\bar{x}$	19.33	47.0	32.67	24.33	38.0	4.33	
	RR	10.3	4.3	1.5	8.2	7.9	23.1	
	σ	1.0	1.0	0.3	1.0	1.7	0.6	
	CV	5.4	2.1	0.9	4.3	4.6	13.3	

(Continued)

TABLE A-28 (continued)

		ALL PRIMARY TEST RESULTS*** (NO REPLICATES)					
Bentonite Id.		1,2,4	3,7,8	9	10	5,6	ALL
Type		A Unalt	B Poly Prot or Ext	C Phys Alt	D Phys Alt-AT	E Chem Trtd	ALL
BASELINE Slurry (0% Acetone)	$\overline{x}$	13.75	30.5	[16]	[26]	7.4	18.95
	RR	79.1	74.6	--	--	30.5	193.9
	σ	5.9	11.5	--	--	--	11.3
	CV	42.9	37.8	--	--	--	59.5
CHEMICALLY HYDRATED Slurry (25% Acetone)	$\overline{x}$	23.8	39.8	[44]	[57]	15.75	32.45
	RR	18.9	26.4	--	--	60.3	138.7
	σ	3.5	5.5	--	--	--	14.0
	CV	14.9	13.8	--	--	--	43.2
WATER HYDRATED CHEMICAL Slurry (25% Acetone)	$\overline{x}$	19.67	35.2	[24]	[37]	39.0	30.35
	RR	33.1	54.0	--	--	124.4	140.0
	σ	3.4	9.7	--	--	--	13.75
	CV	17.3	27.8	--	--	--	45.3

* Includes operator and batching variability

** Operator variability; may include type variability for unaltered bentonites

*** Includes operator, type, and batching variability

Values in parentheses ( ) include "outlier" results
Values in brackets [ ] represent single sample

TABLE A-29. STATISTICAL PARAMETERS - YIELD POINT TEST

		PRIMARY TESTS WITH REPLICATION*						ANALYST** PROFICIENCY
Bentonite Id.		1	3	7	9	10	5	2
Type		A Unalt	B Poly Prot(or)	B Poly Ext	C Phys Alt	D Phys Alt-AT	E Chem Trtd	A Unalt
No. of Reps		3	(3) 2	3	3 2	3	3	
BASELINE Slurry (0% Acetone)	x	4.6	(17.0) 19.5	12.5	6.5	16.2	0.167	11.33
	RR	21.8	(47.1) 5.1	24.0	15.4	15.5	300	8.8
	σ	0.5	(4.4) 0.7	1.7	0.5	1.3	0.3	0.6
	CV	11.4	(25.6) 3.6	13.9	7.7	7.8	1.7	5.1
CHEMICALLY HYDRATED Slurry (25% Acetone)	$\bar{x}$	19.3[illegible]	39.0	30.33	(36.67) 46.0	32.3	11.33	
	RR	10.3	7.7	3.3	8.7 (81.8)	3.1	8.8	
	σ	1.15	1.7	0.6	(16.3) 2.8	0.6	0.6	
	CV	6.0	4.4	1.9	(44.4) 6.1	1.8	5.1	
WATER HYDRATED CHEMICAL Slurry (25% Acetone)	$\bar{x}$	10.67	38.0	23.33	12.0	24.0	10.0	
	RR	18.7	10.5	4.3	16.7	25.0	30.0	
	σ	1.5	2.0	0.6	1.0	3.5	1.7	
	CV	14.3	5.3	2.5	8.3	14.4	17.3	

(Continued)

TABLE A-29 (continued)

		ALL PRIMARY TEST RESULTS*** (NO REPLICATES)					
Bentonite Id.		1,2,4	3,7,8	9	10	5,6	ALL
Type		A Unalt	B Poly Prot or Ext.	C Phys Alt	D Phys Alt-AT	E Chem Trtd	ALL
BASELINE Slurry (0% Acetone)	$\overline{x}$	7.0	26.2	[6]	[16]	0.25	12.2
	RR	139.3	124.2	--	--	200.0	377.0
	σ	5.2	17.4	--	--	--	13.6
	CV	75.0	66.5	--	--	--	111.5
CHEMICALLY HYDRATED Slurry (25% Acetone)	$\overline{x}$	13.0	39.67	[44]	[32]	10.0	25.4
	RR	84.6	47.9	--	--	20.0	161.4
	σ	6.1	9.6	--	--	--	15.6
	CV	46.8	24.2	--	--	--	61.5
WATER HYDRATED CHEMICAL Slurry (25% Acetone)	$\overline{x}$	8.67	26.33	[24]	[22]	28.0	20.2
	RR	57.7	91.1	--	--	121.4	193.1
	σ	2.5	12.3	--	--	--	13.0
	CV	29.0	46.9	--	--	--	64.6

* Includes operator and batching variability

** Operator variability; may include type variability for unaltered bentonites

*** Includes operator, type, and batching variability

Values in parentheses ( ) include "outlier" results
Values in brackets [ ] represent single sample

TABLE A-30. STATISTICAL PARAMETERS - PLASTIC VISCOSITY TEST

		PRIMARY TESTS WITH REPLICATION*						ANALYST** PROFICIENCY
Bentonite Id.		1	3	7	9	10	5	2
Type		A Unalt	B Poly Prot(or)	B Poly Ext	C Phys Alt	D Phys Alt-AT	E Chem Trtd	A Unalt
No. of Reps		3	3	3	3	3	3	3
BASELINE Slurry (0% Acetone)	$\bar{x}$	9.1	19.9	13.8	12.33	17.5	6.2	17.0
	RR	2.8	20.1	7.2	12.2	8.6	8.1	0.0
	σ	0.14	2.2	0.6	0.8	0.9	0.3	0.0
	CV	1.6	11.3	4.2	6.2	4.9	4.7	0.0
CHEMICALLY HYDRATED Slurry (25% Acetone)	$\bar{x}$	17.67	20.33	19.0	21.33	39.33	1.67	--
	RR	5.7	14.8	10.5	4.7	7.6	60.0	--
	σ	0.6	1.5	1.0	0.6	1.5	0.6	--
	CV	3.3	7.5	5.3	2.7	3.9	34.6	--
WATER HYDRATED CHEMICAL Slurry (25% Acetone)	$\bar{x}$	24.0	28.0	21.0	18.67	26.0	12.67	--
	RR	21.4	14.3	0.0	5.4	0.0	7.9	--
	σ	1.7	2.0	0.0	0.6	0.0	0.6	--
	CV	12.4	7.1	0.0	3.1	0.0	4.6	--

(Continued)

TABLE A-30 (continued)

		ALL PRIMARY TEST RESULTS*** (NO REPLICATES)					
Bentonite Id.		1,2,4	3,7,8	9	10	5,6	ALL
Type		A Unalt	B Poly Prot or Ext	C Phys Alt	D Phys Alt-AT	E Chem Trtd	ALL
BASELINE Slurry (0% Acetone)	$\bar{x}$	10.4	17.4	[13]	[18]	7.25	12.9
	RR	57.6	37.3	--	--	34.5	108.5
	σ	3.2	3.4	--	--	--	4.9
	CV	30.4	19.8	--	--	--	38.0
CHEMICALLY HYDRATED Slurry (25% Acetone)	$\bar{x}$	17.33	19.67	[22]	[41]	9.0	19.2
	RR	28.8	10.2	--	--	155.6	203.1
	σ	2.5	1.2	--	--	--	9.5
	CV	14.5	5.9	--	--	--	49.6
WATER HYDRATED CHEMICAL Slurry (25% Acetone)	$\bar{x}$	15.33	22.0	[19]	[26]	25.0	20.3
	RR	39.1	31.8	--	--	96.0	118.2
	σ	3.2	3.6	--	--	--	7.2
	CV	21.0	16.4	--	--	--	35.5

* Includes operator and batching variability
** Operator variability; may include type variability for unaltered bentonites
*** Includes operator, type, and batching variability

Values in parentheses ( ) include "outlier" results
Values in brackets [ ] represent single sample

TABLE A-31. STATISTICAL PARAMETERS - API FILTRATE LOSS TEST

		PRIMARY TESTS WITH REPLICATION*						ANALYST** PROFICIENCY
Bentonite Id.		1	3	7	9	10	5	2
Type		A Unalt	B Poly Prot(or)	B Poly Ext	C Phys Alt	D Phys Alt-AT	E Chem Trtd	A Unalt
No. of Reps		(3) 2	3	3	3	(3) 2	3	3
BASELINE Slurry (0% Acetone)	$\bar{x}$	21.9	21.4	19.4	11.1	(9.4) 8.75	14.67	14.7
	RR	4.1	15.4	13.9	6.3	(21.2) 1.1	6.8	7.5
	σ	0.5	1.9	1.4	0.4	(1.2) 0.07	0.6	0.6
	CV	2.2	8.8	7.0	3.2	(12.6) 0.8	3.9	3.8
CHEMICALLY HYDRATED Slurry (25% Acetone)	$\bar{x}$	(14.8) 13.2	22.5	15.4	9.0	7.0	16.5	--
	RR	(36.5) 9.1	3.1	2.6	12.3	11.4	1.8	--
	σ	(2.8) 0.8	0.4	0.2	0.5	0.4	0.15	--
	CV	(19.2) 6.4	1.8	1.3	6.1	6.2	0.9	--
WATER HYDRATED CHEMICAL Slurry (25% Acetone)	$\bar{x}$	15.8	19.8	19.8	8.5	6.8	14.6	--
	RR	1.9	6.1	10.1	2.4	7.4	10.3	--
	σ	0.15	0.7	1.0	0.1	0.25	0.8	--
	CV	1.0	3.4	5.2	1.2	3.7	5.6	--

(Continued)

TABLE A-31 (continued)

Bentonite Id.		1,2,4	3,7,8	9	10	5,6	ALL
		ALL PRIMARY TEST RESULTS*** (NO REPLICATES)					
Type		A Unalt	B Poly Prot or Ext	C Phys Alt	D Phys Alt-AT	E Chem Trtd	ALL
BASELINE Slurry (0% Acetone)	$\bar{x}$	20.5	19.8	[10.8]	[8.8]	12.3	16.5
	RR	38.0	37.4	--	--	8.9	89.6
	σ	4.3	3.7	--	--	--	5.5
	CV	20.8	18.7	--	--	--	33.3
CHEMICALLY HYDRATED Slurry (25% Acetone)	$\bar{x}$	16.0	17.2	[9.0]	[7.5]	14.6	14.5
	RR	37.5	53.5	--	--	25.3	104.5
	σ	3.5	4.9	--	--	--	4.5
	CV	21.7	28.2	--	--	--	31.3
WATER HYDRATED CHEMICAL Slurry (25% Acetone)	$\bar{x}$	14.33	17.1	[8.4]	[6.8]	26.8	13.1
	RR	27.9	32.7	--	--	7.5	93.3
	σ	2.2	3.2	--	--	--	4.5
	CV	15.4	18.9	--	--	--	34.5

* Includes operator and batching variability

** Operator variability; may include type variability for unaltered bentonites

*** Includes operator, type, and batching variability

Values in parentheses ( ) include "outlier" results

Values in brackets [ ] represent single sample

TABLE A-32. STATISTICAL PARAMETERS - UNIT FILTRATE LOSS TEST

		PRIMARY TESTS WITH REPLICATION*						ANALYST** PROFICIENCY
Bentonite Id.		1	3	7	9	10	5	2
Type		A Unalt	B Poly Prot(or)	B Poly Ext	C Phys Alt	D Phys Alt-AT	E Chem Trtd	A Unalt
No. of Reps		3	3	3	3	3	3	4
BASELINE Slurry (0% Acetone)	x	8.9	6.0	4.9	7.5	5.0	7.1	8.2
	RR	20.3	33.3	16.3	57.3	44.3	82.7	51.2
	σ	0.9	1.0	0.4	2.2	1.1	3.0	2.1
	CV	10.2	16.9	8.9	28.9	22.3	41.6	26.0
CHEMICALLY HYDRATED Slurry (25% Acetone)	$\bar{x}$	7.2	6.4	3.7	3.2	2.5	4.5	--
	RR	41.7	6.3	5.4	21.6	44.6	20.1	--
	σ	1.5	0.2	0.1	0.3	0.6	0.5	--
	CV	21.0	3.6	2.7	10.9	23.1	11.0	--
WATER HYDRATED CHEMICAL Slurry (25% Acetone)	$\bar{x}$	6.0	5.33	6.9	4.3	5.2	8.2	--
	RR	10.0	11.3	14.4	48.8	7.7	23.3	--
	σ	0.3	0.3	0.5	1.0	0.2	1.0	--
	CV	5.8	6.0	7.9	24.5	3.8	12.5	--

(Continued)

TABLE A-32 (continued)

		ALL PRIMARY TEST RESULTS*** (NO REPLICATES)					
Bentonite Id.		1,2,4	3,7,8	9	10	5,6	ALL
Type		A Unalt	B Poly Prot or Ext	C Phys Alt	D Phys Alt-AT	E Chem Trtd	ALL
BASELINE Slurry (0% Acetone)	$\bar{x}$	9.1	6.4	[9.8]	[3.8]	11.15	8.2
	RR	64.8	44.0	--	--	65.5	133.7
	σ	3.0	1.5	--	--	--	3.3
	CV	33.1	23.2	--	--	--	40.7
CHEMICALLY HYDRATED Slurry (25% Acetone)	$\bar{x}$	5.9	5.1	[3.6]	[3.1]	6.5	5.3
	RR	37.1	54.5	--	--	80.0	113.4
	σ	1.1	1.4	--	--	--	1.9
	CV	19.2	27.3	--	--	--	35.6
WATER HYDRATED CHEMICAL Slurry (25% Acetone)	$\bar{x}$	6.4	6.2	[4.4]	[5.2]	5.1	5.75
	RR	23.6	35.5	--	--	74.5	73.0
	σ	0.9	1.1	--	--	--	1.3
	CV	14.1	17.7	--	--	--	23.2

* Includes operator and batching variability

** Operator variability; may include type variability for unaltered bentonites

*** Includes operator, type, and batching variability

Values in parentheses ( ) include "outlier" results
Values in brackets [ ] represent single sample

TABLE A-33. STATISTICAL PARAMETERS - FREE SWELL (24 HR) TEST

		PRIMARY TESTS WITH REPLICATION*						ANALYST** PROFICIENCY
Bentonite Id.		1	3	7	9	10	5	2
Type		A Unalt	B Poly Prot(or)	B Poly Ext	C Phys Alt	D Phys Alt-AT	E Chem Trtd	A Unalt
No. of Reps		3	(3) 2	3	3	3	3	0
BASELINE Slurry (0% Acetone)	$\bar{x}$	35.0	(35.2) 32.25	38.67	26.33	33.2	15.67	--
	RR	8.6	(25.6) 1.6	3.9	11.4	7.5	19.1	--
	σ	1.5	(5.1) 0.35	0.8	1.5	1.3	1.5	--
	CV	4.3	(14.4) 1.1	2.0	5.8	3.8	9.8	--
CHEMICALLY HYDRATED Slurry (25% Acetone)	$\bar{x}$	53.67	42.2	53.2	38.0	43.0	18.0	--
	RR	1.9	1.2	0.9	5.3	3.5	0.0	--
	σ	0.6	0.3	0.3	1.0	0.9	0.0	--
	CV	1.1	0.7	0.5	2.6	2.0	0.0	--
WATER HYDRATED CHEMICAL Slurry (25% Acetone)	$\bar{x}$	--	--	--	--	--	--	--
	RR	--	--	--	--	--	--	--
	σ	--	--	--	--	--	--	--
	CV	--	--	--	--	--	--	--

(Continued)

TABLE A-33 (continued)

		ALL PRIMARY TEST RESULTS*** (NO REPLICATES)					
Bentonite Id.		1,2,4	3,7,8	9	10	5,6	ALL
Type		A Unalt	B Poly Prot or Ext	C Phys Alt	D Phys Alt-AT	E Chem Trtd	ALL
BASELINE Slurry (0% Acetone)	$\overline{x}$	30.5	37.2	[25]	[34.5]	17.0	29.6
	RR	44.3	22.9	--	--	0.0	80.9
	σ	6.9	4.3	--	--	--	8.6
	CV	22.5	11.6	--	--	--	29.1
CHEMICALLY HYDRATED Slurry (25% Acetone)	$\overline{x}$	38.3	47.33	[37]	[42]	17.5	37.1
	RR	70.4	23.2	--	--	5.7	97.0
	σ	13.65	5.5	--	--	--	13.1
	CV	35.6	11.6	--	--	--	35.3
WATER HYDRATED CHEMICAL Slurry (25% Acetone)	$\overline{x}$	--	--	--	--	--	--
	RR	--	--	--	--	--	--
	σ	--	--	--	--	--	--
	CV	--	--	--	--	--	--

* Includes operator and batching variability

** Operator variability; may include type variability for unaltered bentonites

*** Includes operator, type, and batching variability

Values in parentheses ( ) include "outlier" results

Values in brackets [ ] represent single sample

TABLE A-34. STATISTICAL PARAMETERS - SLURRY DENSITY (MUD WT) TEST

		PRIMARY TESTS WITH REPLICATION*						ANALYST** PROFICIENCY
Bentonite Id.		1 A	3 B	7 B	9 C	10 D	5 E	2 A
Type		Unalt	Poly Prot(or)	Poly Ext	Phys Alt	Phys Alt-AT	Chem Trtd	Unalt
No. of Reps		3	3	3	3	3	3	4
BASELINE Slurry (0% Acetone)	x̄	64.7	64.5	64.5	64.6	64.75	64.25	64.5
	RR	0.5	0.0	0.4	0.4	0.0	0.0	0.5
	σ	0.2	0.0	0.14	0.14	0.0	0.0	0.225
	CV	0.3	0.0	0.2	0.2	0.0	0.0	0.3
CHEMICALLY HYDRATED Slurry (25% Acetone)	x̄	63.2	63.1	63.1	62.8	62.8	62.8	--
	RR	0.4	0.8	0.4	0.4	0.4	0.4	--
	σ	0.14	0.3	0.14	0.14	0.14	0.14	--
	CV	0.2	0.5	0.2	0.2	0.2	0.2	--
WATER HYDRATED CHEMICAL Slurry (25% Acetone)	x̄	62.9	63.8	62.9	62.6	62.6	62.8	--
	RR	0.4	0.4	0.3	0.4	0.4	1.2	--
	σ	0.14	0.14	0.11	0.14	0.13	0.4	--
	CV	0.2	0.2	0.2	0.2	0.2	0.6	--

(Continued)

TABLE A-34 (continued)

		ALL PRIMARY TEST RESULTS*** (NO REPLICATES)					ALL
Bentonite Id.		1,2,4 A	3,7,8 B	9 C	10 D	5,6 E	ALL
Type		Unalt	Poly Prot or Ext	Phys Alt	Phys Alt-AT	Chem Trtd	ALL
BASELINE Slurry (0% Acetone)	$\overline{x}$	64.55	64.4	[64.5]	[64.75]	64.4	64.5
	RR	0.9	0.3	--	--	0.4	0.9
	σ	0.3	0.1	--	--	--	0.2
	CV	0.4	0.2	--	--	--	0.3
CHEMICALLY HYDRATED Slurry (25% Acetone)	$\overline{x}$	63.2	63.1	[63]	[62.75]	62.75	63.0
	RR	0.4	0.4	--	--	0.0	0.8
	σ	0.14	0.14	--	--	--	0.2
	CV	0.2	0.2	--	--	--	0.3
WATER HYDRATED CHEMICAL Slurry (25% Acetone)	$\overline{x}$	63.1	63.0	[62.75]	[62.67]	63.0	62.9
	RR	2.0	2.3	--	--	0.7	2.3
	σ	0.6	0.7	--	--	--	0.5
	CV	1.0	1.2	--	--	--	0.8

* Includes operator and batching variability

** Operator variability; may include type variability for unaltered bentonites

*** Includes operator, type, and batching variability

Values in parentheses ( ) include "outlier" results

Values in brackets [ ] represent single sample

TABLE A-35. STATISTICAL PARAMETERS - SPECIFIC CONDUCTANCE TEST

		PRIMARY TESTS WITH REPLICATION*						ANALYST** PROFICIENCY
Bentonite Id.		1	3	7	9	10	5	2
Type		A Unalt	B Poly Prot(or)	B Poly Ext	C Phys Alt	D Phys Alt-AT	E Chem Trtd	A Unalt
No. of Reps		3	3	3	3	(3) 2	3	
BASELINE Slurry (0% Acetone)	$\bar{x}$	0.926	0.978	0.839	0.772	0.791	0.90	--
	RR	8.8	2.5	9.2	13.6	12.4	14.4	--
	σ	.043	.012	.039	.061	.049	.07	--
	CV	4.6	1.2	4.6	7.9	6.2	7.8	--
CHEMICALLY HYDRATED	$\bar{x}$	.533	.550	.499	.419	(.364) .408	.435	--
	RR	9.9	15.1	10.2	8.1	(35.7) 0.2	11.7	--
Slurry (25% Acetone)	σ	.03	.043	.026	.017	(.075) .001	.029	--
	CV	5.7	7.8	5.1	4.1	(20.5) 0.2	6.8	--
WATER HYDRATED CHEMICAL Slurry (25% Acetone)	$\bar{x}$	.546	.569	.498	.437	.441	.601	--
	RR	17.8	5.8	10.6	9.4	1.1	14.3	--
	σ	0.05	.019	.027	.023	.003	.047	--
	CV	9.3	3.3	5.4	5.4	0.6	7.8	--

(Continued)

TABLE A-35 (continued)

Bentonite Id.		1,2,4 A	3,7,8 B	9 C	10 D	5,6 E	ALL
		ALL PRIMARY TEST RESULTS*** (NO REPLICATES)					
Type		Unalt	Poly Prot or Ext	Phys Alt	Phys Alt-AT	Chem Trtd	ALL
BASELINE Slurry (0% Acetone)	$\bar{x}$	0.863	0.857	[.737]	[.794]	1.091	0.887
	RR	21.7	21.6	--	--	29.5	53.0
	σ	.097	.104	--	--	--	.153
	CV	11.2	12.1	--	--	--	17.3
CHEMICALLY HYDRATED Slurry (25% Acetone)	$\bar{x}$	.498	.506	[.422]	[.408]	.465	.477
	RR	27.5	17.2	--	--	20.0	33.5
	σ	.069	.049	--	--	--	5.8
	CV	13.8	9.6	--	--	--	12.2
WATER HYDRATED CHEMICAL Slurry (25% Acetone)	$\bar{x}$	.490	.477	[.450]	[.443]	.561	.492
	RR	8.8	28.7	--	--	22.1	43.3
	σ	.023	.069	--	--	--	.06
	CV	4.7	14.4	--	--	--	12.2

* Includes operator and batching variability
** Operator variability; may include type variability for unaltered bentonites
*** Includes operator, type, and batching variability

Values in parentheses ( ) include "outlier" results
Values in brackets [ ] represent single sample

APPENDIX B

SECONDARY TEST RESULTS

Raw Data; Tables B-1 through B-4

Raw Data; Figures B-1 and B-2

TABLE B-1. SECONDARY INDICATOR TEST RESULTS (phase II)

Type: UNALTERED			CHEMICALLY 'HYDRATED' Slurry			WATER HYDRATED Chemical Slurry		
Bentonite Id: 1			% CHEMICAL IN DEIONIZED WATER					
IND. TEST	LOT	CHEMICAL	0 (BASELINE Slurry)	25	R1	25	R1	50
MARSH FUNNEL VISCOSITY (sec)	1	Acetone	36.4	68.5	72.1	49.2	49.9	55.4
	2	Acetone	34.2	72.6	74.4	52.0	45.5	51.2
	2	Methanol	"	36.3	37.5	57.0	56.0	35.4
API UNIT FILTRATE LOSS (ml/mm)	1	Acetone	6.7	5.0	5.8	6.2	6.1	5.1
	2	Acetone	3.2	5.4	5.7	5.9	6.3	7.1
	2	Methanol	"	6.3	6.2	8.6	6.5	9.7
SPECIFIC CONDUCTANCE (mmhos)	1	Acetone	.385	.508	.498	.620	.536	.369
	2	Acetone	1.144	.794	.795	.719	.735	.368
	2	Methanol	"	.696	.699	.410	.411	.482

NOTE: Slurry not remixed prior to test

TABLE B-2. SECONDARY INDICATOR TEST RESULTS (phase II)

Type: POLYMER PROTECTED			CHEMICALLY 'HYDRATED' Slurry			WATER HYDRATED Chemical Slurry		
Bentonite Id: 3			% CHEMICAL IN DEIONIZED WATER					
IND. TEST	LOT	CHEMICAL	0 (BASELINE Slurry)	25	R1	25	R1	50
MARSH FUNNEL VISCOSITY (sec)	1	Acetone	(383)	(653)	(536)	(230.2)	(226.3)	66.1
	2	Acetone	30.4	41.9	39.0	36.1	33.3	39.5
	2	Methanol	"	29.2	28.8	111.8	89.4	62.4
API UNIT FILTRATE LOSS (ml/mm)	1	Acetone	6.2	3.6	5.9	4.2	4.5	5.6
	2	Acetone	9.9	9.2	8.3	7.9	7.2	10.0
	2	Methanol	"	9.5	11.5	5.5	6.6	4.8
SPECIFIC CONDUCTANCE (mmhos)	1	Acetone	.856	0.444	.481	.593	.622	.307
	2	Acetone	1.025	.563	.563	.543	.561	.273
	2	Methanol	"	.486	.487	.555	.555	.386

NOTE: Slurry not remixed prior to test
"outliers" in parenthesis

TABLE B-3. SECONDARY INDICATOR TEST RESULTS (phase II)

Type: PHYSICALLY ALTERED			CHEMICALLY 'HYDRATED' Slurry			WATER HYDRATED Chemical Slurry		
Bentonite Id: 9			% CHEMICAL IN DEIONIZED WATER					
IND. TEST	LOT	CHEMICAL	0 (BASELINE Slurry)	25	R1	25	R1	50
MARSH FUNNEL VISCOSITY (sec)	1	Acetone	43.0	93.2	85.3	57.3	54.0	150.9
	2	Acetone	48	95	83	216.8	196.9	61.9
	2	Methanol	"	36.5	35.7	30.8	28.1	30.7
API UNIT FILTRATE	1	Acetone	5.5	5.4	5	5.2	4.4	2.9
	2	Acetone	6.0	4.7	5.4	5.9	7.5	6.9
(ml/mn)	2	Methanol	"	9.1	6.3	11.7	10.2	12.4
SPECIFIC CONDUCTANCE (mmhos)	1	Acetone	.657	.367	.383	.475	.471	.317
	2	Acetone	.702	.670	.675	.548	.569	.249
	2	Methanol	"	.541	.541	.435	.436	.309

NOTE: Slurry not remixed prior to test

TABLE B-4. SECONDARY INDICATOR TEST RESULTS (phase II)

Type: CHEMICALLY TREATED			CHEMICALLY 'HYDRATED' Slurry			WATER HYDRATED Chemical Slurry		
Bentonite Id: 6			% CHEMICAL IN DEIONIZED WATER					
IND. TEST	LOT	CHEMICAL	0 (BASELINE Slurry)	25	R1	25	R1	50
MARSH FUNNEL VISCOSITY (sec)	1	Acetone	36.9	48.8	48.1	38.3	38.6	32.3
	2	Acetone	29.3	39.9	39.3	41.8	38.1	38.3
	2	Methanol	"	38.3	36.4	41.0	40.1	41.5
API UNIT FILTRATE LOSS (ml/mm)	1	Acetone	10.1	7.4	9.3	7.1	7.3	6.1
	2	Acetone	7.6	7.1	6.7	6.6	6.3	8.6
	2	Methanol	"	9.3	9.8	6.6	6.7	8.5
SPECIFIC CONDUCTANCE (mmhos)	1	Acetone	1.07	.557	.582	.700	.703	.412
	2	Acetone	1.039	.631	.572	.726	.730	.479
	2	Methanol	"	.574	.562	.785	.792	.642

NOTE: Slurry not remixed prior to test

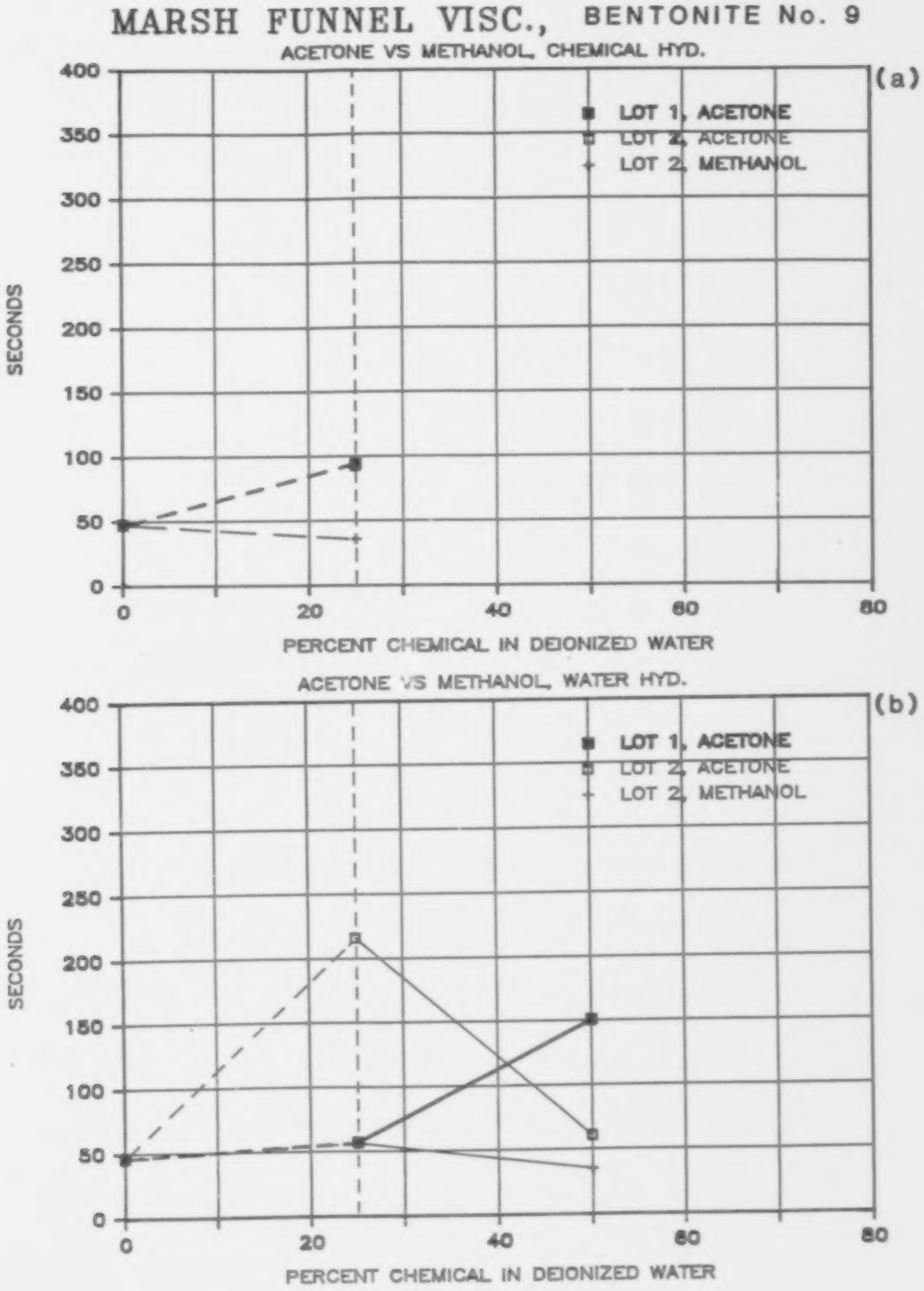
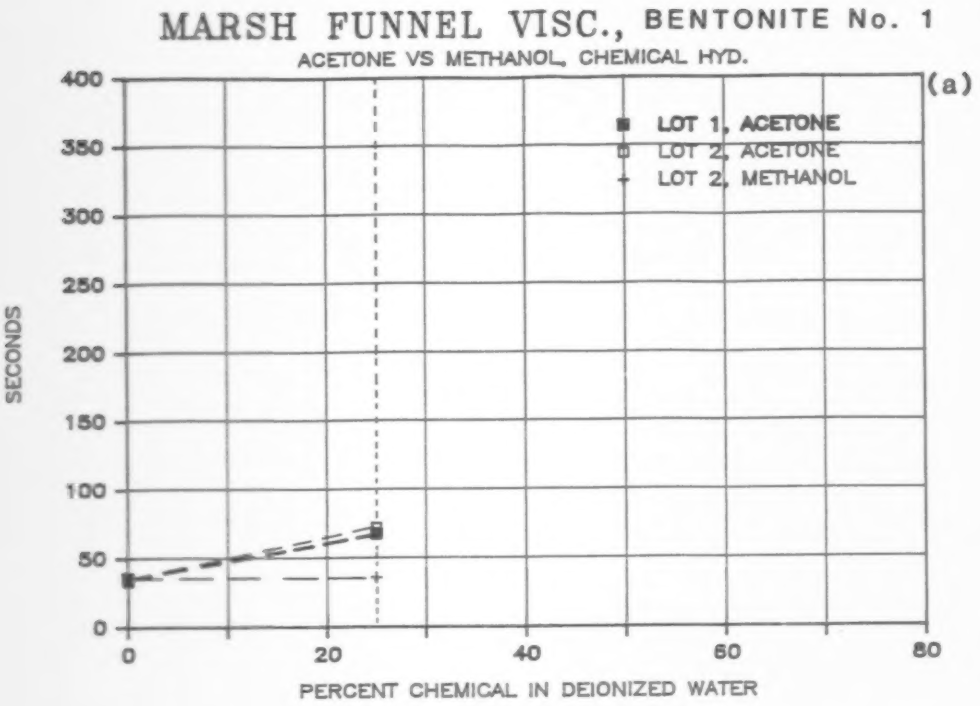


Figure B-1: Secondary indicator test results for Marsh Funnel Viscosity test.



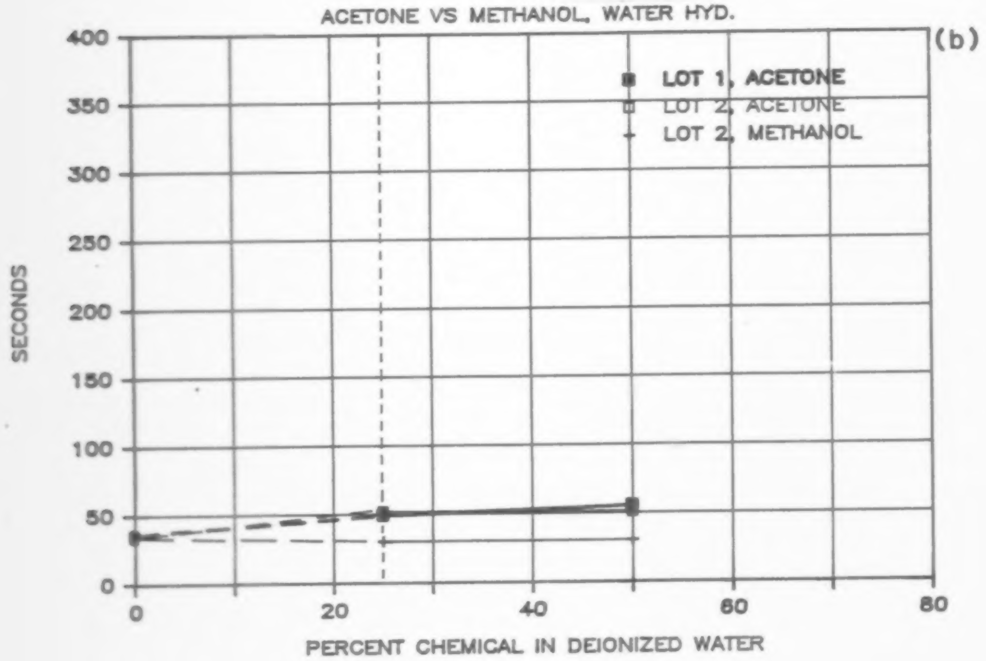


Figure B-1: (continued)

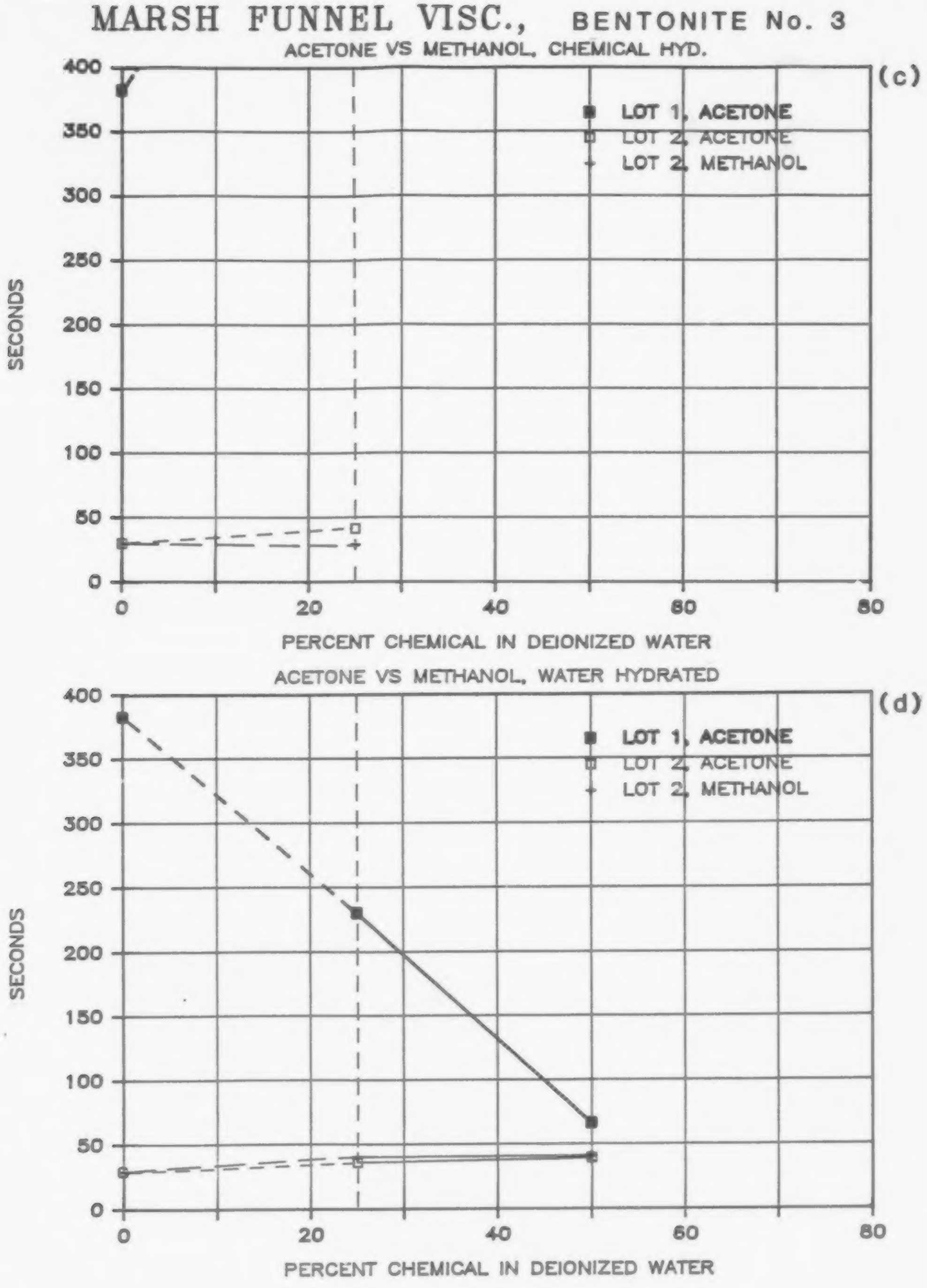


Figure B-1: (continued)

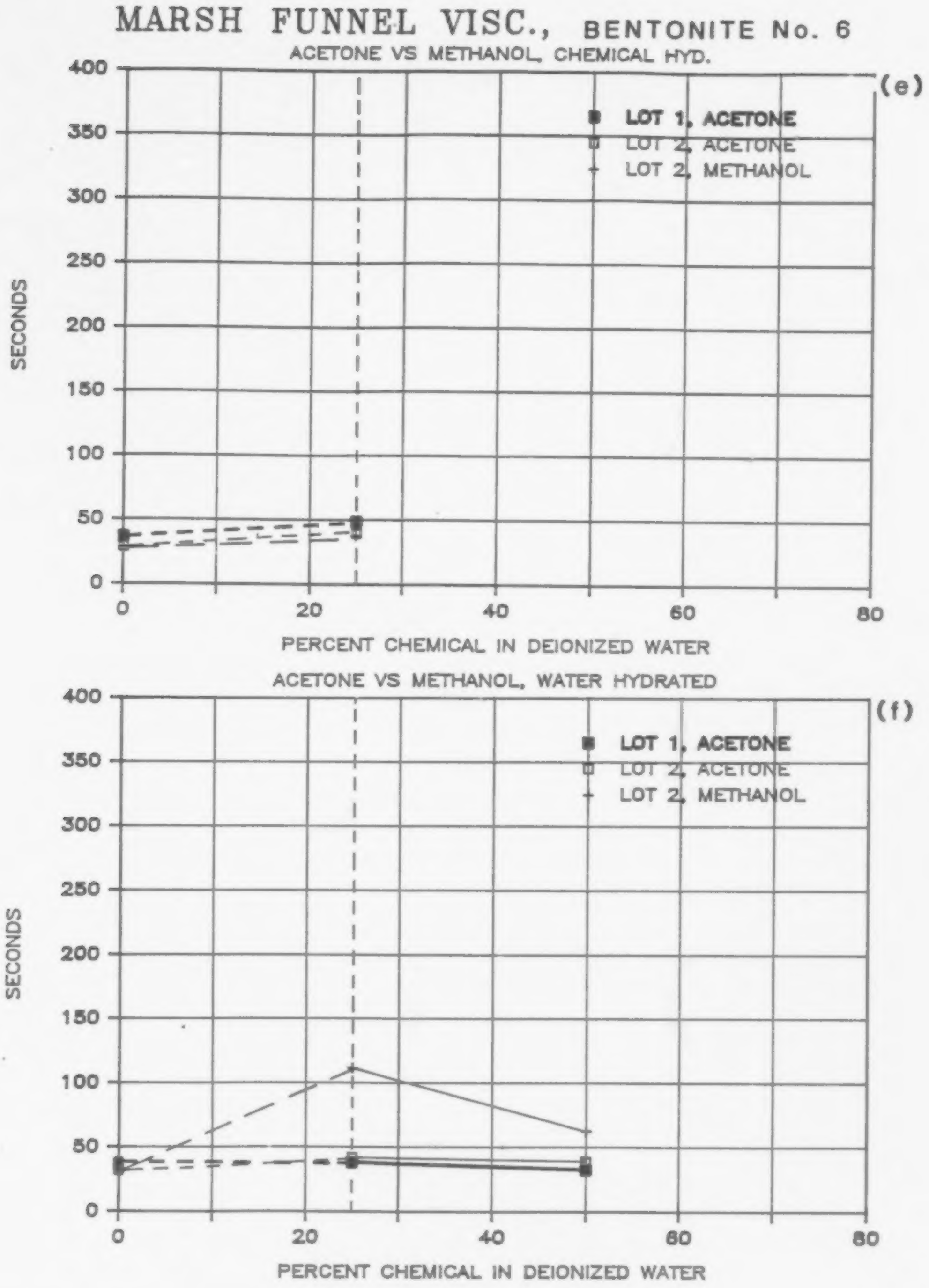


Figure B-1: (continued)

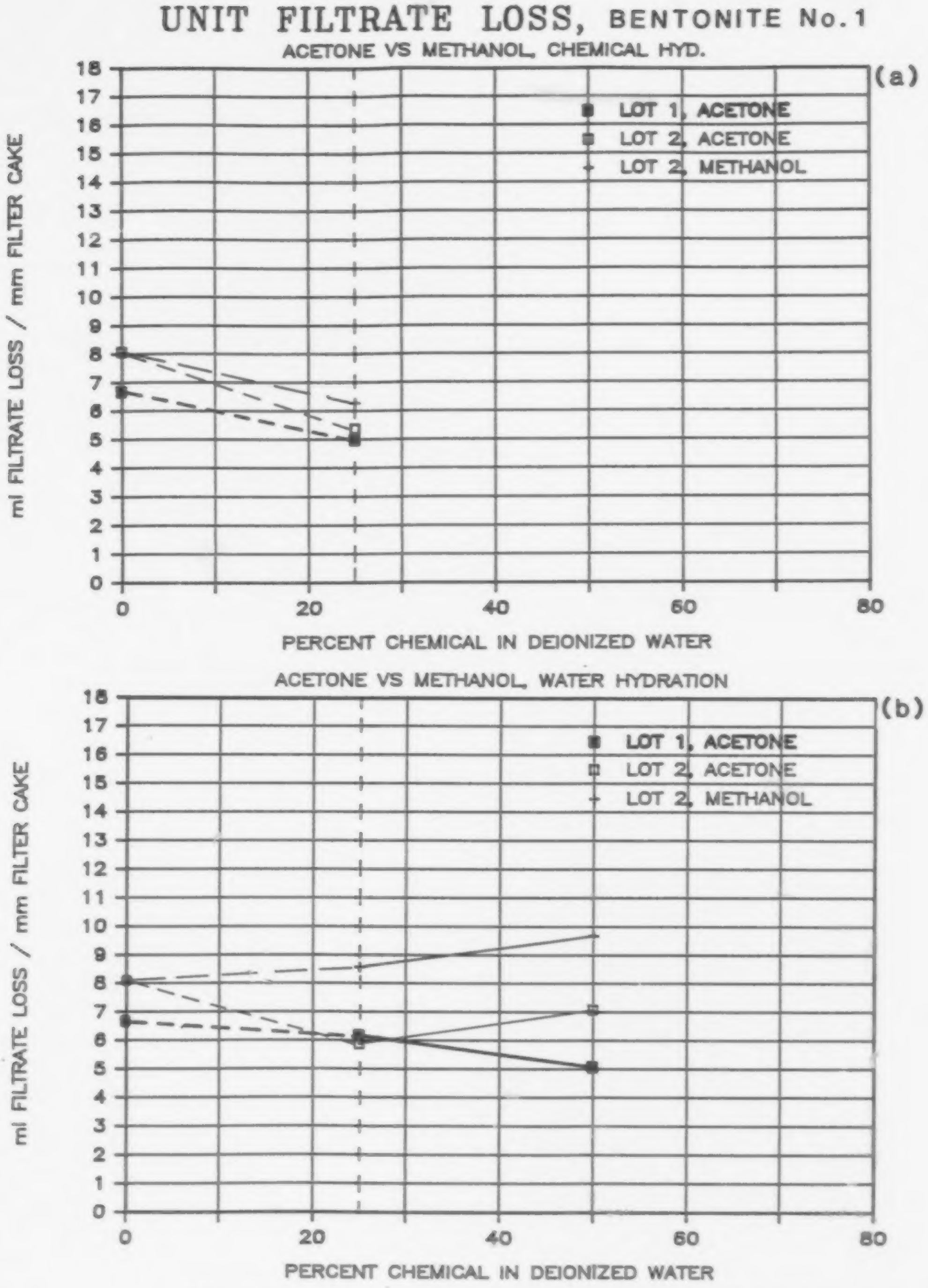


Figure B-2: Secondary indicator test results for Unit Filtrate Loss test.

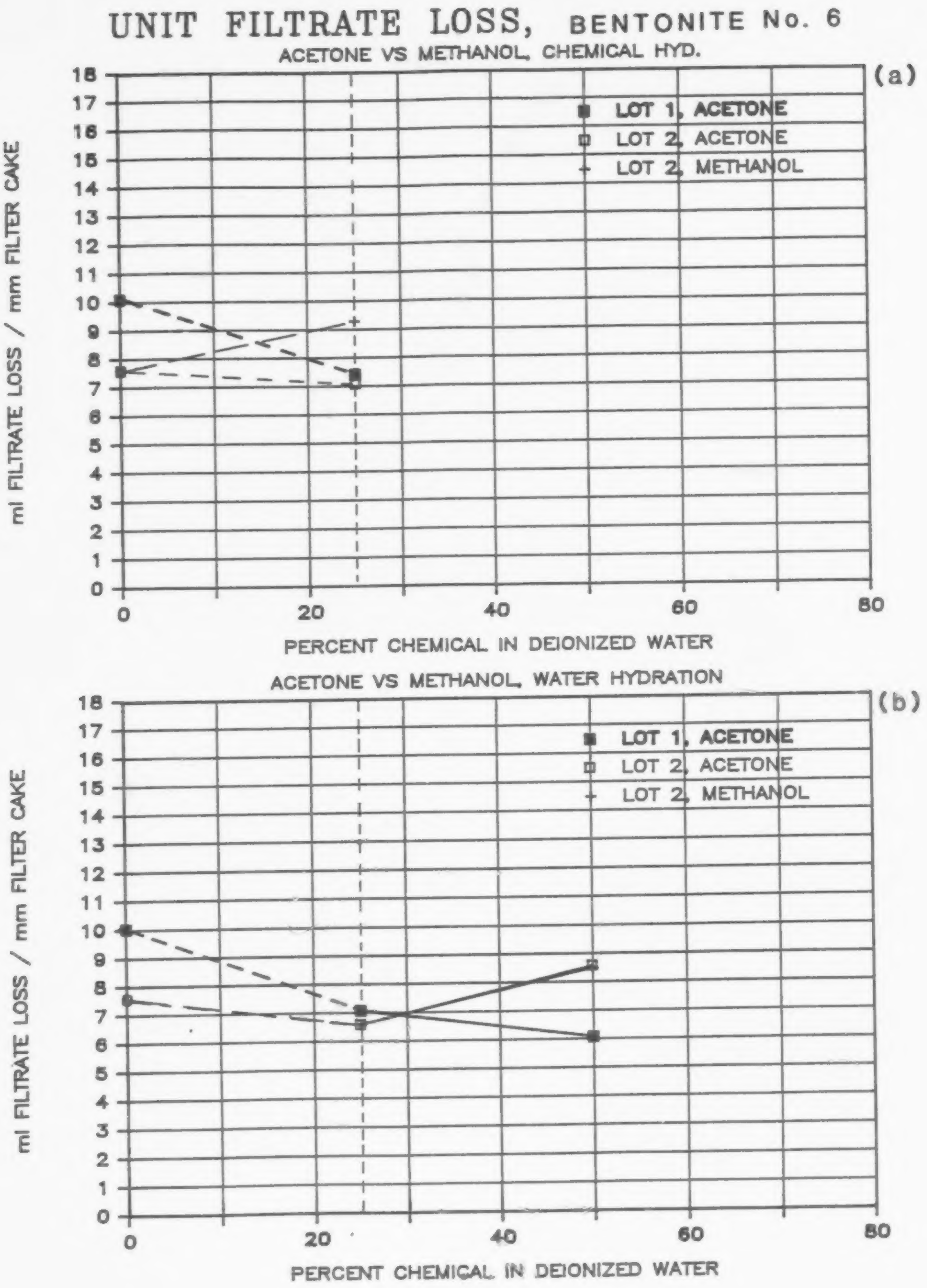


Figure B-2: (continued)

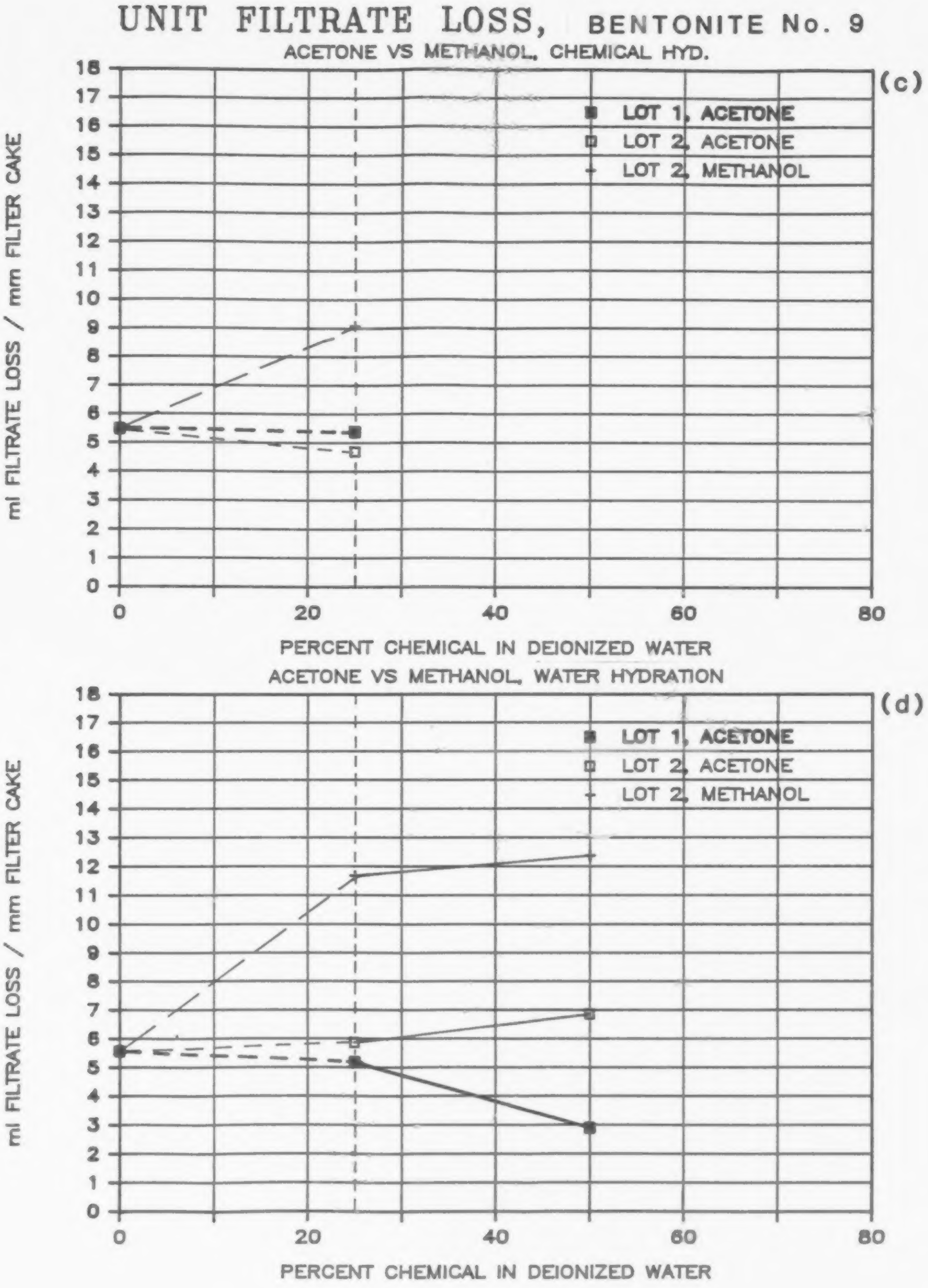


Figure B-2: (continued)

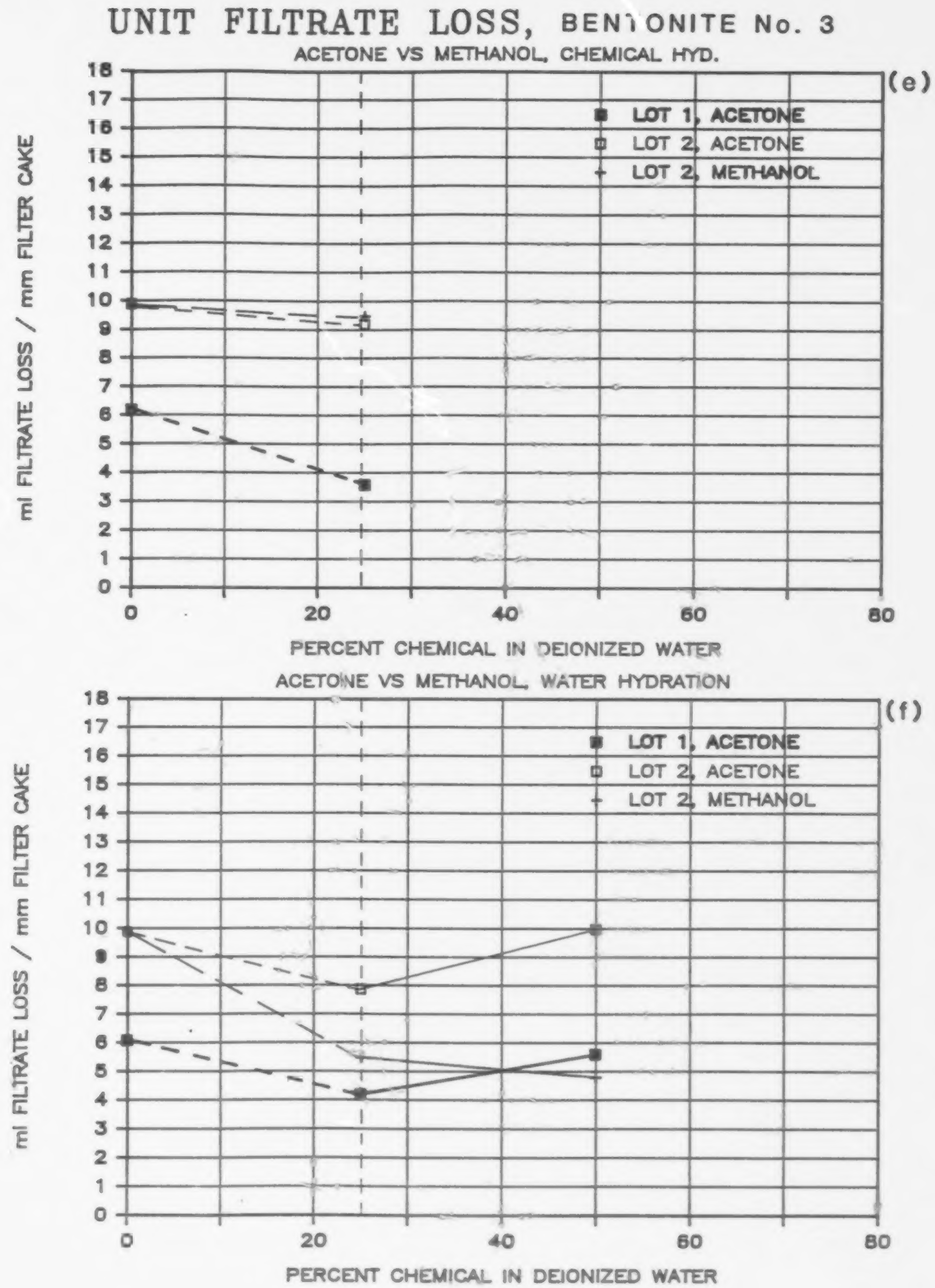


Figure B-2: (continued)

APPENDIX C

PERMEABILITY AND CORRELATION TEST RESULTS

Raw Data; Tables C-1 through C-20

Raw Data; Figures C-1 through C-18

Filter Cake Correlation Plots;

Figures C-19 through C-26

TABLE C-1 PRIMARY INDICATOR TEST RESULTS (Phase III)

Type: UNALTERED; 3%	CHEMICALLY 'HYDRATED' Slurry							
Bentonite Id: 1	% ACETONE IN DEIONIZED WATER							
INDICATOR TEST	0 (BASELINE Slurry)	R_1	R_2	5	15	25	R_1	R_2
A. MARSH FUNNEL VISCOSITY (sec)	28.3	27.1	-	-	-	-	-	-
B. GEL STRENGTH (lb/100 ft^2)								
- 10 sec	0.0	0.0	-	-	-	-	-	-
- 10 min	0.0	0.0	-	-	-	-	-	-
C. APPARENT VISCOSITY (cP)	4.5	4.5	-	-	-	-	-	-
D. YIELD POINT (lb/100 ft^2)	0.0	0.0	-	-	-	-	-	-
E. PLASTIC VISCOSITY (cP)	4.5	4.5	-	-	-	-	-	-
F. FREE SWELL -2 hr.	-	-	-	-	-	-	-	-
-24 hr.	-	-	-	-	-	-	-	-
G. MUD WEIGHT (pcf)	-	-	-	-	-	-	-	-
H. SPECIFIC CONDUCTANCE (mmhos)	-	-	-	-	-	-	-	-
J. API FILTRATE LOSS								
(ml)	24.0	23.5	-	-	-	-	-	-
cake thickness [mm]	1.49	1.48	-	-	-	-	-	-
(ml/mm)	16.1	15.9	-	-	-	-	-	-
K. pH	-	-	-	-	-	-	-	-
Slurry Temperature (°C)	-	-	-	-	-	-	-	-
RUN:	-	-	-	-	-	-	-	-

(continued)

NOTE: Slurry remixed immediately prior to test

TABLE C-1 (continued)

Type: UNALTERED; 3%	WATER HYDRATED Chemical Slurry						
Bentonite Id: 1	% ACETONE IN DEIONIZED WATER						
INDICATOR TEST	5	15	25	R_1	R_2	50	75*
A. MARSH FUNNEL VISCOSITY (sec)	-	-	30.1	-	-	30.3	-
B. GEL STRENGTH (lb/100 ft^2)							
- 10 sec	-	-	0.0	-	-	1.0	-
- 10 min	-	-	0.0	-	-	6.0	-
C. APPARENT VISCOSITY (cP)	-	-	6.0	-	-	6.5	-
D. YIELD POINT (lb/100 ft^2)	-	-	2.0	-	-	3.0	-
E. PLASTIC VISCOSITY (cP)	-	-	5.0	-	-	5.0	-
F. FREE SWELL -2 hr.	-	-	-	-	-	-	-
-24 hr.	-	-	-	-	-	-	-
G. MUD WEIGHT (pcf)	-	-	-	-	-	-	-
H. SPECIFIC CONDUCTANCE (mmhos)	-	-	-	-	-	-	-
J. API FILTRATE LOSS							
(ml)	-	-	17.2	-	-	18.0	-
cake thickness [mm]	-	-	1.25	-	-	1.10	-
(ml/mm)	-	-	13.8	-	-	16.4	-
K. ph	-	-	-	-	-	-	-
Slurry Temperature (°C)	-	-	-	-	-	-	-
RUN:	-	-	-	-	-	-	-

NOTE: Slurry remixed immediately prior to test

TABLE C-2 PRIMARY INDICATOR TEST RESULTS (Phase III)

Type: UNALTERED; 5%	CHEMICALLY 'HYDRATED' Slurry							
Bentonite Id: 1	% ACETONE IN DEIONIZED WATER							
INDICATOR TEST	0 (BASELINE Slurry)	R_1	R_2	5	15	25	R_1	R_2
A. MARSH FUNNEL VISCOSITY (sec)	36.6	35.7	-	-	-	-	-	-
B. GEL STRENGTH (lb/100 ft^2)								
- 10 sec	0.5	1.5	-	-	-	-	-	-
- 10 min	9.0	9.5	-	-	-	-	-	-
C. APPARENT VISCOSITY (cP)	13.5	13.0	-	-	-	-	-	-
D. YIELD POINT (lb/100 ft^2)	5.0	4.0	-	-	-	-	-	-
E. PLASTIC VISCOSITY (cP)	11.0	11.0	-	-	-	-	-	-
F. FREE SWELL -2 hr.	-	-	-	-	-	-	-	-
-24 hr.	-	-	-	-	-	-	-	-
G. MUD WEIGHT (pcf)	-	-	-	-	-	-	-	-
H. SPECIFIC CONDUCTANCE (mmhos)	-	-	-	-	-	-	-	-
J. API FILTRATE LOSS								
(ml)	16.9	15.5	-	-	-	-	-	-
cake thickness [mm]	2.4	2.1	-	-	-	-	-	-
(ml/mm)	7.1	7.4	-	-	-	-	-	-
K. pH	-	-	-	-	-	-	-	-
Slurry Temperature (°C)	-	-	-	-	-	-	-	-
RUN:	-	-	-	-	-	-	-	-

(continued)

NOTE: Slurry remixed immediately prior to test

TABLE C-2 (continued)

Type: UNALTERED; 5%	WATER HYDRATED Chemical Slurry						
Bentonite Id: 1	% ACETONE IN DEIONIZED WATER						
INDICATOR TEST	5	15	25	R_1	R_2	50	75*
A. MARSH FUNNEL VISCOSITY (sec)	-	-	37.6	-	-	44.8	-
B. GEL STRENGTH (lb/100 ft^2)							
- 10 sec	-	-	5.0	-	-	6.0	-
- 10 min	-	-	15.0	-	-	11.0	-
C. APPARENT VISCOSITY (cP)	-	-	13.5	-	-	16.0	-
D. YIELD POINT (lb/100 ft^2)	-	-	5.0	-	-	10.0	-
E. PLASTIC VISCOSITY (cP)	-	-	9.0	-	-	11.0	-
F. FREE SWELL -2 hr.	-	-	-	-	-	-	-
-24 hr.	-	-	-	-	-	-	-
G. MUD WEIGHT (pcf)	-	-	-	-	-	-	-
H. SPECIFIC CONDUCTANCE (mmhos)	-	-	-	-	-	-	-
J. API FILTRATE LOSS							
(ml)	-	-	12.5	-	-	12.5	-
cake thickness [mm]	-	-	1.60	-	-	2.15	-
(ml/mm)	-	-	7.8	-	-	5.8	-
K. pH	-	-	-	-	-	-	-
Slurry Temperature (°C)	-	-	-	-	-	-	-
RUN:	-	-	-	-	-	-	-

NOTE: Slurry remixed immediately prior to test

TABLE C-3 PRIMARY INDICATOR TEST RESULTS (Phase III)

Type: UNALTERED; 7%	CHEMICALLY 'HYDRATED' Slurry							
Bentonite Id: 1	% ACETONE IN DEIONIZED WATER							
INDICATOR TEST	0 (BASELINE Slurry)	R_1	R_2	5	15	25	R_1	R_2
A. MARSH FUNNEL VISCOSITY (sec)	88.3	83.2	-	-	-	-	-	-
B. GEL STRENGTH (lb/100 ft^2)								
- 10 sec	15.0	15.0	-	-	-	-	-	-
- 10 min	23.0	19.0	-	-	-	-	-	-
C. APPARENT VISCOSITY (cP)	30.0	30.5	-	-	-	-	-	-
D. YIELD POINT (lb/100 ft^2)	20.0	21.0	-	-	-	-	-	-
E. PLASTIC VISCOSITY (cP)	20.0	20.0	-	-	-	-	-	-
F. FREE SWELL -2 hr.	-	-	-	-	-	-	-	-
-24 hr.	-	-	-	-	-	-	-	-
G. MUD WEIGHT (pcf)	-	-	-	-	-	-	-	-
H. SPECIFIC CONDUCTANCE (mmhos)	-	-	-	-	-	-	-	-
J. API FILTRATE LOSS								
(ml)	12.3	12.3	-	-	-	-	-	-
cake thickness [mm]	3.70	3.36	-	-	-	-	-	-
(ml/mm)	3.3	3.7	-	-	-	-	-	-
K. pH	-	-	-	-	-	-	-	-
Slurry Temperature (°C)	-	-	-	-	-	-	-	-
RUN:	-	-	-	-	-	-	-	-

(continued)

NOTE: Slurry remixed immediately prior to test

TABLE C-3 (continued)

Type: UNALTERED; 7%	WATER HYDRATED Chemical Slurry						
Bentonite Id: 1	% ACETONE IN DEIONIZED WATER						
INDICATOR TEST	5	15	25	R_1	R_2	50	75*
A. MARSH FUNNEL VISCOSITY (sec)	-	-	117.7	-	-	165.3	-
B. GEL STRENGTH (lb/100 ft^2)							
- 10 sec	-	-	28.0	-	-	18.0	-
- 10 min	-	-	24.0	-	-	39.0	-
C. APPARENT VISCOSITY (cP)	-	-	32.5	-	-	38.5	-
D. YIELD POINT (lb/100 ft^2)	-	-	27.0	-	-	15.0	-
E. PLASTIC VISCOSITY (cP)	-	-	19.0	-	-	31.0	-
F. FREE SWELL -2 hr.	-	-	-	-	-	-	-
-24 hr.	-	-	-	-	-	-	-
G. MUD WEIGHT (pcf)	-	-	-	-	-	-	-
H. SPECIFIC CONDUCTANCE (mmhos)	-	-	-	-	-	-	-
J. API FILTRATE LOSS							
(ml)	-	-	9.3	-	-	10.0	-
cake thickness [mm]	-	-	2.54	-	-	2.69	-
(ml/mm)	-	-	3.6	-	-	3.7	-
K. pH	-	-	-	-	-	-	-
Slurry Temperature (°C)	-	-	-	-	-	-	-
RUN:	-	-	-	-	-	-	-

NOTE: Slurry remixed immediately prior to test

TABLE C-4 PRIMARY INDICATOR TEST RESULTS (Phase III)

Type: POLYMER PROTECTED; 3%	CHEMICALLY 'HYDRATED' Slurry							
Bentonite Id: 3	% ACETONE IN DEIONIZED WATER							
INDICATOR TEST	0 (BASELINE Slurry)	R_1	R_2	5	15	25	R_1	R_2
A. MARSH FUNNEL VISCOSITY (sec)	27.6	26.9	-	-	-	-	-	-
B. GEL STRENGTH (lb/100 ft^2)								
- 10 sec	0.0	0.0	-	-	-	-	-	-
- 10 min	0.0	0.0	-	-	-	-	-	-
C. APPARENT VISCOSITY (cP)	3.5	3.5	-	-	-	-	-	-
D. YIELD POINT (lb/100 ft^2)	3.0	2.0	-	-	-	-	-	-
E. PLASTIC VISCOSITY (cP)	2.0	2.5	-	-	-	-	-	-
F. FREE SWELL -2 hr.	-	-	-	-	-	-	-	-
-24 hr.	-	-	-	-	-	-	-	-
G. MUD WEIGHT (pcf)	-	-	-	-	-	-	-	-
H. SPECIFIC CONDUCTANCE (mmhos)	-	-	-	-	-	-	-	-
J. API FILTRATE LOSS								
(ml)	23.0	22.0	-	-	-	-	-	-
cake thickness [mm]	1.38	1.34	-	-	-	-	-	-
(ml/mm)	16.7	16.4	-	-	-	-	-	-
K. pH	-	-	-	-	-	-	-	-
Slurry Temperature (°C)	-	-	-	-	-	-	-	-
RUN:	-	-	-	-	-	-	-	-

(continued)

NOTE: Slurry remixed immediately prior to test

TABLE C-4 (continued)

Type: POLYMER PROTECTED; 3%	WATER HYDRATED Chemical Slurry						
Bentonite Id: 3	% ACETONE IN DEIONIZED WATER						
INDICATOR TEST	5	15	25	R_1	R_2	50	75
A. MARSH FUNNEL VISCOSITY (sec)	-	-	28.1	-	-	30.0	-
B. GEL STRENGTH (lb/100 ft^2)							
- 10 sec	-	-	0.0	-	-	0.0	-
- 10 min	-	-	0.0	-	-	0.0	-
C. APPARENT VISCOSITY (cP)	-	-	4.0	-	-	6.0	-
D. YIELD POINT (lb/100 ft^2)	-	-	0.0	-	-	0.0	-
E. PLASTIC VISCOSITY (cP)	-	-	4.0	-	-	6.0	-
F. FREE SWELL -2 hr.	-	-	-	-	-	-	-
-24 hr.	-	-	-	-	-	-	-
G. MUD WEIGHT (pcf)	-	-	-	-	-	-	-
H. SPECIFIC CONDUCTANCE (mmhos)	-	-	-	-	-	-	-
J. API FILTRATE LOSS (ml)	-	-	20.2	-	-	20.1	-
cake thickness [mm]	-	-	0.85	-	-	1.06	-
(ml/mm)	-	-	23.8	-	-	19.0	-
K. pH	-	-	-	-	-	-	-
Slurry Temperature (°C)	-	-	-	-	-	-	-
RUN:	-	-	-	-	-	-	-

NOTE: Slurry remixed immediately prior to test

TABLE C-5 PRIMARY INDICATOR TEST RESULTS (Phase III)

Type: POLYME PROTECTED; 5%	CHEMICALLY 'HYDRATED' Slurry							
Bentonite Id: 3	% ACETONE IN DEIONIZED WATER							
INDICATOR TEST	0 (BASELINE Slurry)	R_1	R_2	5	15	25	R_1	R_2
A. MARSH FUNNEL VISCOSITY (sec)	34.4	33.4	-	-	-	-	-	-
B. GEL STRENGTH (lb/100 ft^2)								
- 10 sec	0.0	0.0	-	-	-	-	-	-
- 10 min	0.5	0.5	-	-	-	-	-	-
C. APPARENT VISCOSITY (cP)	11.5	10.0	-	-	-	-	-	-
D. YIELD POINT (lb/100 ft^2)	2.0	2.0	-	-	-	-	-	-
E. PLASTIC VISCOSITY (cP)	10.5	9.0	-	-	-	-	-	-
F. FREE SWELL -2 hr.	-	-	-	-	-	-	-	-
-24 hr.	-	-	-	-	-	-	-	-
G. MUD WEIGHT (pcf)	-	-	-	-	-	-	-	-
H. SPECIFIC CONDUCTANCE (mmhos)	-	-	-	-	-	-	-	-
J. API FILTRATE LOSS (ml)	15.5	16.3	-	-	-	-	-	-
cake thickness [mm]	1.65	1.49	-	-	-	-	-	-
(ml/mm)	9.4	10.9	-	-	-	-	-	-
K. pH	-	-	-	-	-	-	-	-
Slurry Temperature (°C)	-	-	-	-	-	-	-	-
RUN:	-	-	-	-	-	-	-	-

(continued)

NOTE: Slurry remixed immediately prior to test

TABLE C-5 (continued)

Type: POLYMER PROTECTED; 5%	WATER HYDRATED Chemical Slurry						
Bentonite Id: 3	% ACETONE IN DEIONIZED WATER						
INDICATOR TEST	5	15	25	R_1	R_2	50	75*
A. MARSH FUNNEL VISCOSITY (sec)	-	-	32.9	-	-	31.4	-
B. GEL STRENGTH (lb/100 ft^2)							
- 10 sec	-	-	0.0	-	-	0.5	-
- 10 min	-	-	0.0	-	-	1.0	-
C. APPARENT VISCOSITY (cP)	-	-	8.5	-	-	6.5	-
D. YIELD POINT (lb/100 ft^2)	-	-	1.0	-	-	1.0	-
E. PLASTIC VISCOSITY (cP)	-	-	8.0	-	-	6.0	-
F. FREE SWELL -2 hr.	-	-	-	-	-	-	-
-24 hr.	-	-	-	-	-	-	-
G. MUD WEIGHT (pcf)	-	-	-	-	-	-	-
H. SPECIFIC CONDUCTANCE (mmhos)	-	-	-	-	-	-	-
J. API FILTRATE LOSS							
(ml)	-	-	13.6	-	-	17.8	-
cake thickness [mm]	-	-	1.14	-	-	1.16	-
(ml/mm)	-	-	11.9	-	-	15.3	-
K. pH	-	-	-	-	-	-	-
Slurry Temperature (°C)	-	-	-	-	-	-	-
RUN:	-	-	-	-	-	-	-

NOTE: Slurry remixed immediately prior to test

TABLE C-6 PRIMARY INDICATOR TEST RESULTS (Phase III)

Type: POLYMER PROTECTED; 7%	CHEMICALLY 'HYDRATED' Slurry							
Bentonite Id: 3	% ACETONE IN DEIONIZED WATER							
INDICATOR TEST	0 (BASELINE Slurry)	R_1	R_2	5	15	25	R_1	R_2
A. MARSH FUNNEL VISCOSITY (sec)	43.4	42.3	-	-	-	-	-	-
B. GEL STRENGTH (lb/100 ft^2)								
- 10 sec	0.5	0.5	-	-	-	-	-	-
- 10 min	0.75	1.0	-	-	-	-	-	-
C. APPARENT VISCOSITY (cP)	22.8	21.5	-	-	-	-	-	-
D. YIELD POINT (lb/100 ft^2)	8.5	8.0	-	-	-	-	-	-
E. PLASTIC VISCOSITY (cP)	18.5	17.5	-	-	-	-	-	-
F. FREE SWELL -2 hr.	-	-	-	-	-	-	-	-
-24 hr.	-	-	-	-	-	-	-	-
G. MUD WEIGHT (pcf)	-	-	-	-	-	-	-	-
H. SPECIFIC CONDUCTANCE (mmhos)	-	-	-	-	-	-	-	-
J. API FILTRATE LOSS								
(ml)	12.4	13.2	-	-	-	-	-	-
cake thickness [mm]	2.23	2.28	-	-	-	-	-	-
(ml/mm)	5.6	5.8	-	-	-	-	-	-
K. pH	-	-	-	-	-	-	-	-
Slurry Temperature (°C)	-	-	-	-	-	-	-	-
RUN:	-	-	-	-	-	-	-	-

(continued)

NOTE: Slurry remixed immediately prior to test

TABLE C-6 (continued)

Type: POLYMER PROTECTED; 7%	WATER HYDRATED Chemical Slurry						
Bentonite Id: 3	% ACETONE IN DEIONIZED WATER						
INDICATOR TEST	5	15	25	R_1	R_2	50	75*
A. MARSH FUNNEL VISCOSITY (sec)	-	-	45.7	-	-	60.1	-
B. GEL STRENGTH (lb/100 ft^2)							
- 10 sec	-	-	0.5	-	-	8.0	-
- 10 min	-	-	5.0	-	-	17.0	-
C. APPARENT VISCOSITY (cP)	-	-	21.0	-	-	24.5	-
D. YIELD POINT (lb/100 ft^2)	-	-	6.0	-	-	11.0	-
E. PLASTIC VISCOSITY (cP)	-	-	18.0	-	-	19.0	-
F. FREE SWELL -2 hr.	-	-	-	-	-	-	-
-24 hr.	-	-	-	-	-	-	-
G. MUD WEIGHT (pcf)	-	-	-	-	-	-	-
H. SPECIFIC CONDUCTANCE (mmhos)	-	-	-	-	-	-	-
J. API FILTRATE LOSS							
(ml)	-	-	11.8	-	-	13.5	-
cake thickness [mm]	-	-	1.80	-	-	2.09	-
(ml/mm)	-	-	6.6	-	-	6.5	-
K. pH	-	-	-	-	-	-	-
Slurry Temperature (°C)	-	-	-	-	-	-	-
RUN:	-	-	-	-	-	-	-

NOTE: Slurry remixed immediately prior to test

TABLE C-7 PRIMARY INDICATOR TEST RESULTS (Phase III)

Type: CHEMICALLY TREATED; 3%	CHEMICALLY 'HYDRATED' Slurry							
Bentonite Id: 6	% ACETONE IN DEIONIZED WATER							
INDICATOR TEST	0 (BASELINE Slurry)	R_1	R_2	5	15	25	R_1	R_2
A. MARSH FUNNEL VISCOSITY (sec)	28.0	27.4	-	-	-	-	-	-
B. GEL STRENGTH (lb/100 ft^2)								
- 10 sec	0.0	0.0	-	-	-	-	-	-
- 10 min	0.0	0.0	-	-	-	-	-	-
C. APPARENT VISCOSITY (cP)	3.5	3.3	-	-	-	-	-	-
D. YIELD POINT (lb/100 ft^2)	1.0	0.5	-	-	-	-	-	-
E. PLASTIC VISCOSITY (cP)	3.0	3.0	-	-	-	-	-	-
F. FREE SWELL -2 hr.	-	-	-	-	-	-	-	-
-24 hr.	-	-	-	-	-	-	-	-
G. MUD WEIGHT (pcf)	-	-	-	-	-	-	-	-
H. SPECIFIC CONDUCTANCE (mmhos)	-	-	-	-	-	-	-	-
J. API FILTRATE LOSS								
(ml)	18.9	19.0	-	-	-	-	-	-
cake thickness [mm]	0.98	0.99	-	-	-	-	-	-
(ml/mm)	19.3	19.2	-	-	-	-	-	-
K. pH	-	-	-	-	-	-	-	-
Slurry Temperature (°C)	-	-	-	-	-	-	-	-
RUN:	-	-	-	-	-	-	-	-

(continued)

NOTE: Slurry remixed immediately prior to test

TABLE C-7 (continued)

Type: CHEMICALLY TREATED; 3%	WATER HYDRATED Chemical Slurry						
Bentonite Id: 6	% ACETONE IN DEIONIZED WATER						
INDICATOR TEST	5	15	25	R_1	R_2	50	75*
A. MARSH FUNNEL VISCOSITY (sec)	-	-	28.2	-	-	30.2	-
B. GEL STRENGTH (lb/100 ft^2)							
- 10 sec	-	-	0.0	-	-	0.0	-
- 10 min	-	-	0.0	-	-	0.0	-
C. APPARENT VISCOSITY (cP)	-	-	4.0	-	-	5.5	-
D. YIELD POINT (lb/100 ft^2)	-	-	0.0	-	-	1.0	-
E. PLASTIC VISCOSITY (cP)	-	-	4.0	-	-	5.0	-
F. FREE SWELL -2 hr.	-	-	-	-	-	-	-
-24 hr.	-	-	-	-	-	-	-
G. MUD WEIGHT (pcf)	-	-	-	-	-	-	-
H. SPECIFIC CONDUCTANCE (mmhos)	-	-	-	-	-	-	-
J. API FILTRATE LOSS							
(ml)	-	-	17.0	-	-	19.8	-
cake thickness [mm]	-	-	0.60	-	-	1.09	-
(ml/mm)	-	-	28.3	-	-	18.1	-
K. pH	-	-	-	-	-	-	-
Slurry Temperature (°C)	-	-	-	-	-	-	-
RUN:	-	-	-	-	-	-	-

NOTE: Slurry remixed immediately prior to test

TABLE C-8 PRIMARY INDICATOR TEST RESULTS (Phase III)

Type: CHEMICALLY TREATED; 5%	CHEMICALLY 'HYDRATED' Slurry							
Bentonite Id: 6	% ACETONE IN DEIONIZED WATER							
INDICATOR TEST	0 (BASELINE Slurry)	R_1	R_2	5	15	25	R_1	R_2
A. MARSH FUNNEL VISCOSITY (sec)	31.3	31.0	-	-	-	-	-	-
B. GEL STRENGTH (lb/100 ft^2)								
- 10 sec	0.0	0.0	-	-	-	-	-	-
- 10 min	0.25	0.0	-	-	-	-	-	-
C. APPARENT VISCOSITY (cP)	8.5	7.8	-	-	-	-	-	-
D. YIELD POINT (lb/100 ft^2)	1.0	1.5	-	-	-	-	-	-
E. PLASTIC VISCOSITY (cP)	8.0	7.0	-	-	-	-	-	-
F. FREE SWELL -2 hr.	-	-	-	-	-	-	-	-
-24 hr.	-	-	-	-	-	-	-	-
G. MUD WEIGHT (pcf)	-	-	-	-	-	-	-	-
H. SPECIFIC CONDUCTANCE (mmhos)	-	-	-	-	-	-	-	-
J. API FILTRATE LOSS								
(ml)	13.1	13.2	-	-	-	-	-	-
cake thickness [mm]	1.16	1.19	-	-	-	-	-	-
(ml/mm)	11.3	11.1	-	-	-	-	-	-
K. pH	-	-	-	-	-	-	-	-
Slurry Temperature (°C)	-	-	-	-	-	-	-	-
RUN:	-	-	-	-	-	-	-	-

(continued)

NOTE: Slurry remixed immediately prior to test

TABLE C-8 (continued)

Type: CHEMICALLY TREATED; 5%	WATER HYDRATED Chemical Slurry						
Bentonite Id: 6	% ACETONE IN DEIONIZED WATER						
INDICATOR TEST	5	15	25	R_1	R_2	50	75*
A. MARSH FUNNEL VISCOSITY (sec)	-	-	31.0	-	-	35.1	-
B. GEL STRENGTH (lb/100 ft^2)							
- 10 sec	-	-	0.0	-	-	0.5	-
- 10 min	-	-	0.0	-	-	3.0	-
C. APPARENT VISCOSITY (cP)	-	-	7.5	-	-	11.5	-
D. YIELD POINT (lb/100 ft^2)	-	-	1.0	-	-	3.0	-
E. PLASTIC VISCOSITY (cP)	-	-	7.0	-	-	10.0	-
F. FREE SWELL -2 hr.	-	-	-	-	-	-	-
-24 hr.	-	-	-	-	-	-	-
G. MUD WEIGHT (pcf)	-	-	-	-	-	-	-
H. SPECIFIC CONDUCTANCE (mmhos)	-	-	-	-	-	-	-
J. API FILTRATE LOSS							
(ml)	-	-	11.8	-	-	17.3	-
cake thickness [mmhos]	-	-	0.98	-	-	1.48	-
(ml/mm)	-	-	12.1	-	-	11.7	-
K. pH	-	-	-	-	-	-	-
Slurry Temperature (°C)	-	-	-	-	-	-	-
RUN:	-	-	-	-	-	-	-

NOTE: Slurry remixed immediately prior to test

TABLE C-9 PRIMARY INDICATOR TEST RESULTS (Phase III)

Type: CHEMICALLY TREATED; 7%	CHEMICALLY 'HYDRATED' Slurry							
Bentonite Id: 6	% ACETONE IN DEIONIZED WATER							
INDICATOR TEST	0 (BASELINE Slurry)	R_1	R_2	5	15	25	R_1	R_2
A. MARSH FUNNEL VISCOSITY (sec)	38.5	37.2	-	-	-	-	-	-
B. GEL STRENGTH (lb/100 ft^2)								
- 10 sec	0.0	0.0	-	-	-	-	-	-
- 10 min	0.5	1.0	-	-	-	-	-	-
C. APPARENT VISCOSITY (cP)	17.0	16.0	-	-	-	-	-	-
D. YIELD POINT (lb/100 ft^2)	4.0	4.0	-	-	-	-	-	-
E. PLASTIC VISCOSITY (cP)	15.0	14.0	-	-	-	-	-	-
F. FREE SWELL -2 hr.	-	-	-	-	-	-	-	-
-24 hr.	-	-	-	-	-	-	-	-
G. MUD WEIGHT (pcf)	-	-	-	-	-	-	-	-
H. SPECIFIC CONDUCTANCE (mmhos)	-	-	-	-	-	-	-	-
J. API FILTRATE LOSS								
(ml)	9.5	10.5	-	-	-	-	-	-
cake thickness [mm]	1.32	1.32	-	-	-	-	-	-
(ml/mm)	7.2	7.9	-	-	-	-	-	-
K. pH	-	-	-	-	-	-	-	-
Slurry Temperature (°C)	-	-	-	-	-	-	-	-
RUN:	-	-	-	-	-	-	-	-

(continued)

NOTE: Slurry remixed immediately prior to test

TABLE C-9 (continued)

Type: CHEMICALLY TREATED; 7%	WATER HYDRATED Chemical Slurry						
Bentonite Id: 6	% ACETONE IN DEIONIZED WATER						
INDICATOR TEST	5	15	25	R_1	R_2	50	75*
A. MARSH FUNNEL VISCOSITY (sec)	-	-	42.1	-	-	56.2	-
B. GEL STRENGTH (lb/100 ft^2)							
- 10 sec	-	-	0.0	-	-	8.0	-
- 10 min	-	-	1.25	-	-	10.0	-
C. APPARENT VISCOSITY (cP)	-	-	18.5	-	-	23.0	-
D. YIELD POINT (lb/100 ft^2)	-	-	7.0	-	-	14.0	-
E. PLASTIC VISCOSITY (cP)	-	-	15.0	-	-	16.0	-
F. FREE SWELL -2 hr.	-	-	-	-	-	-	-
-24 hr.	-	-	-	-	-	-	-
G. MUD WEIGHT (pcf)	-	-	-	-	-	-	-
H. SPECIFIC CONDUCTANCE (mmhos)	-	-	-	-	-	-	-
J. API FILTRATE LOSS							
(ml)	-	-	9.6	-	-	13.0	-
cake thickness [mm]	-	-	1.05	-	-	1.55	-
(ml/mm)	-	-	9.1	-	-	8.4	-
K. pH	-	-	-	-	-	-	-
Slurry Temperature (°C)	-	-	-	-	-	-	-
RUN:	-	-	-	-	-	-	-

NOTE: Slurry remixed immediately prior to test

TABLE C-10 MODIFIED SWELL; EFFECT OF INITIAL WATER CONTENT

Type: UNALTERED	Test No: 1-1	CHEMICAL				
Bentonite Id: 1	W_i = 7.45%	WATER	(R_1)	ACETONE	METHANOL	XYLENE
ELAPSED TIME (hours)						
1		0.04330	0.04760	-	-	-
2		0.05830	0.06370	-	-	-
3		0.06930	0.07545	-	-	-
4		0.07865	0.08540	-	-	-
5		0.08590	0.09320	-	-	-
6		0.09230	0.10040	-	-	-
7		0.09790	0.10595	-	-	-

NOTE: All data cumulative swell in inches; w_i = initial water content, R_1 = replicate test

TABLE C-11 MODIFIED SWELL; EFFECT OF INITIAL WATER CONTENT

Type: UNALTERED	Test No: 1-2	CHEMICAL				
Bentonite Id: 1	W_i = 8.45%	WATER	(R_1)	ACETONE	METHANOL	XYLENE
ELAPSED TIME (hours)						
1		0.03005	0.03475	-	0.03470	-
2		0.04530	0.05155	-	-	-
3		0.05700	0.06420	-	0.05990	-
4		0.06660	0.07475	-	0.06640	-
5		0.07462	0.08300	-	0.07410	-
6		0.08140	0.08990	-	0.08080	-
7		0.08740	0.09590	-	0.10520	-

NOTE: All data cumulative swell in inches; w_i = initial water content, R_1 = replicate test

TABLE C-12 MODIFIED SWELL; EFFECT OF INITIAL WATER CONTENT

Type: UNALTERED	Test No: 1-3	CHEMICAL				
Bentonite Id: 1	W_i = 10.85%	WATER	(R_1)	ACETONE	METHANOL	XYLENE
ELAPSED TIME (hours)						
1.32	(1.28)	0.02305	0.02455	-	-	-
2		0.03359	0.03425	-	-	-
3		0.04475	0.04455	-	-	-
4		0.05387	0.05343	-	-	-
5		0.06075	0.06097	-	-	-
6		0.06695	0.06686	-	-	-
7		0.07275	0.07236	-	-	-

NOTE: All data cumulative swell in inches; w_i = initial water content, R_1 = replicate test

TABLE C-13 MODIFIED SWELL; EFFECT OF INITIAL WATER CONTENT

Type: UNALTERED	Test No: 1-4	CHEMICAL				
Bentonite Id: 1	W_i = 15.4%	WATER	(R_1)	ACETONE	METHANOL	XYLENE
ELAPSED TIME (hours)						
1		0.02390	0.02505	-	-	-
2		0.03590	0.03705	-	-	-
3		0.04340	0.04408	-	-	-
4		0.04975	0.04980	-	-	-
5		0.05358	0.05555	-	-	-
6		0.05740	0.06030	-	-	-
7		0.05940	0.06380	-	-	-

NOTE: All data cumulative swell in inches; w_i = initial water content, R_1 = replicate test

TABLE C-14 MODIFIED SWELL; EFFECT OF INITIAL WATER CONTENT

Type: UNALTERED	Test No: 1-5	CHEMICAL				
Bentonite Id: 1	W_i = 21.34%	WATER	(R_1)	ACETONE	METHANOL	XYLENE
ELAPSED TIME (hours)						
1		0.02684	0.02360	-	-	-
2		0.03534	0.03280	-	-	-
3		0.04164	0.03840	-	-	-
4		0.04714	0.04360	-	-	-
5		0.05224	0.04830	-	-	-
6		0.05674	0.05260	-	-	-
7		0.06064	0.05620	-	-	-

NOTE: All data cumulative swell in inches; w_i = initial water content, R_1 = replicate test

TABLE C-15 MODIFIED SWELL; EFFECT OF INITIAL WATER CONTENT

Type: UNALTERED	Test No: 1-6	CHEMICAL				
Bentonite Id: 1	W_i = 31.36%	WATER	(R_1)	ACETONE	METHANOL	XYLENE
ELAPSED TIME (hours)						
1.45	(1.43)	0.01660	0.01670	-	-	-
2		0.01850	0.01860	-	-	-
3.18	(3.18)	0.02180	0.02230	-	-	-
4.02		0.02420	0.02480	-	-	-
5		0.02680	0.02680	-	-	-
6		0.02900	0.02860	-	-	-
7		0.03100	0.03030	-	-	-

NOTE: All data cumulative swell in inches; w_i = initial water content, R_1 = replicate test

TABLE C-16 MODIFIED SWELL; TYPE-DISTINCTION TESTS

Type: POLYMER PROTECTED	Test No: 3-1	CHEMICAL				
Bentonite Id: 3	W_i = 8.58%	WATER	(R_1)	ACETONE	METHANOL	XYLENE
ELAPSED TIME (hours)						
1		0.05320	0.05420	-	.05240	-
2		0.08390	0.08090	-	.07590	-
3		0.10830	0.10270	-	.09470	-
4		0.12800	0.12030	-	.11020	-
5		0.14560	0.13710	-	.12420	-
6		0.16000	0.15220	-	.13730	-
7		0.17500	0.16690	-	-	-

NOTE: All data cumulative swell in inches; w_i = initial water content, R_1 = replicate test

TABLE C-17 MODIFIED SWELL; TYPE-DISTINCTION TESTS

Type: CHEMICALLY TREATED	Test No: 3-2	CHEMICAL				
Bentonite Id: 6	W_i = 8.43%	WATER	(R_1)	ACETONE	METHANOL	XYLENE
ELAPSED TIME (hours)						
1		0.03420	0.03130	-	0.02270	-
2		0.04830	0.04520	-	0.03100	-
3		0.05920	0.05140	-	0.03710	-
4		0.06808	0.06384	-	0.04300	-
5		0.07684	0.07050	-	0.04780	-
6		0.08242	0.07770	-	0.05150	-
7		0.08800	0.08302	-	-	-

NOTE: All data cumulative swell in inches; w_i = initial water content, R_1 = replicate test

TABLE C-18 MODIFIED SWELL; TYPE-DISTINCTION TESTS

Type: UNALTERED	Test No: 5-1	CHEMICAL				
Bentonite Id: 2	W_i = 8.20%	WATER	(R_1)	ACETONE	METHANOL	XYLENE
ELAPSED TIME (hours)						
1		0.03410	0.03420	-	0.02820	-
2		0.04770	0.04600	-	0.03950	-
3		0.05670	0.05600	-	0.04780	-
4		0.06440	0.06320	-	0.05430	-
5		0.07020	0.06940	-	0.06010	-
6		0.07510	0.07560	-	0.06540	-
7		0.07990	0.08060	-	0.07050	-

NOTE: All data cumulative swell in inches; w_i = initial water content, R_1 = replicate test

TABLE C-19 MODIFIED SWELL; TYPE-DISTINCTION TESTS

Type: POLYMER EXTENDED	Test No: 5-2	CHEMICAL				
Bentonite Id: 8	W_i = 8.26%	WATER	(R_1)	ACETONE	METHANOL	XYLENE
ELAPSED TIME (hours)						
1		0.05290	0.05660	-	0.04580	-
2		0.07320	0.07680	-	0.06450	-
3		0.08800	0.09120	-	0.07840	-
4		0.10010	0.10300	-	0.08960	-
5		0.11090	0.11340	-	0.09900	-
6		0.11960	0.12180	-	0.10760	-
7		0.12750	0.12950	-	0.11460	-

NOTE: All data cumulative swell in inches; w_i = initial water content, R_1 = replicate test

TABLE C-20 MODIFIED SWELL; TYPE-DISTINCTION TESTS

Type: CHEMICALLY TREATED	Test No: 5-3	CHEMICAL				
Bentonite Id: 5	W_i = 8.16%	WATER	(R_1)	ACETONE	METHANOL	XYLENE
ELAPSED TIME (hours)						
1		0.04970	0.05070	-	0.03770	-
2		0.06850	0.06920	-	0.05190	-
3		0.08200	0.08280	-	0.06190	-
4		0.09270	0.09330	-	0.07000	-
5		0.10270	0.10340	-	0.07750	-
6		0.11070	0.11100	-	0.08320	-
7		0.11730	0.11790	-	0.08880	-

NOTE: All data cumulative swell in inches; w_i = initial water content, R_1 = replicate test

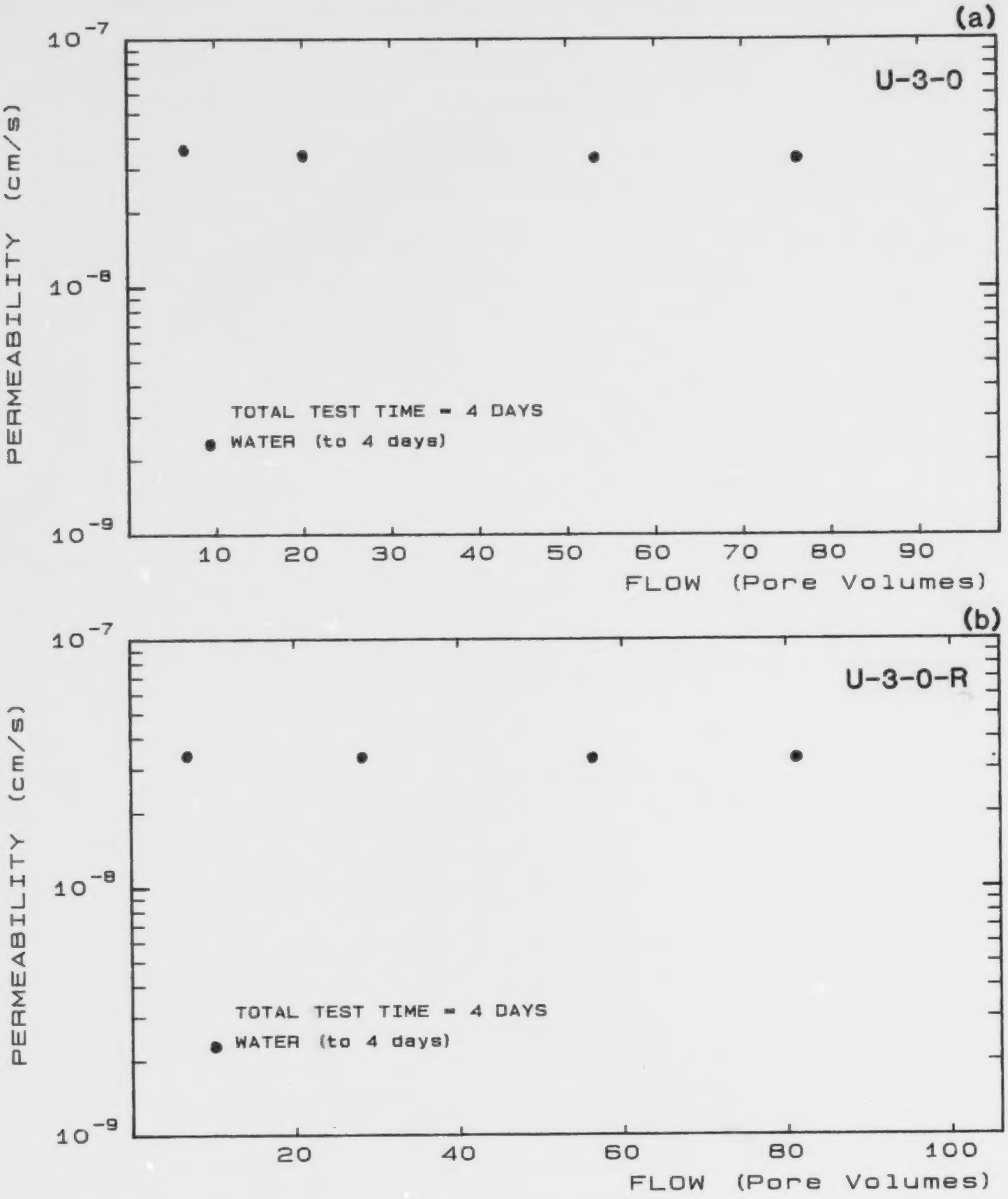


Figure C-1: Hydraulic conductivity of filter cake formed from 3% slurry of unaltered bentonite no. 1.

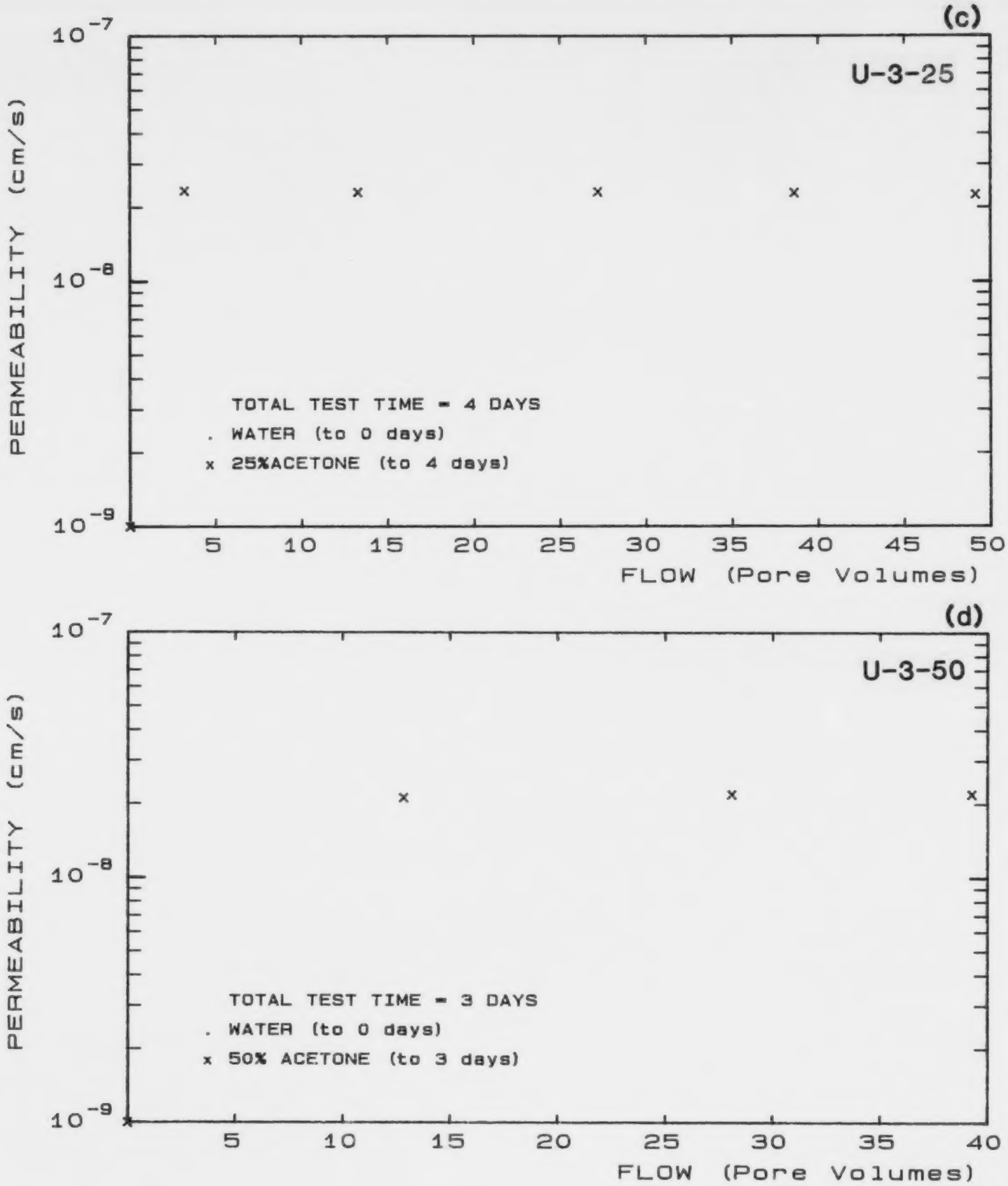


Figure C-1. (continued)

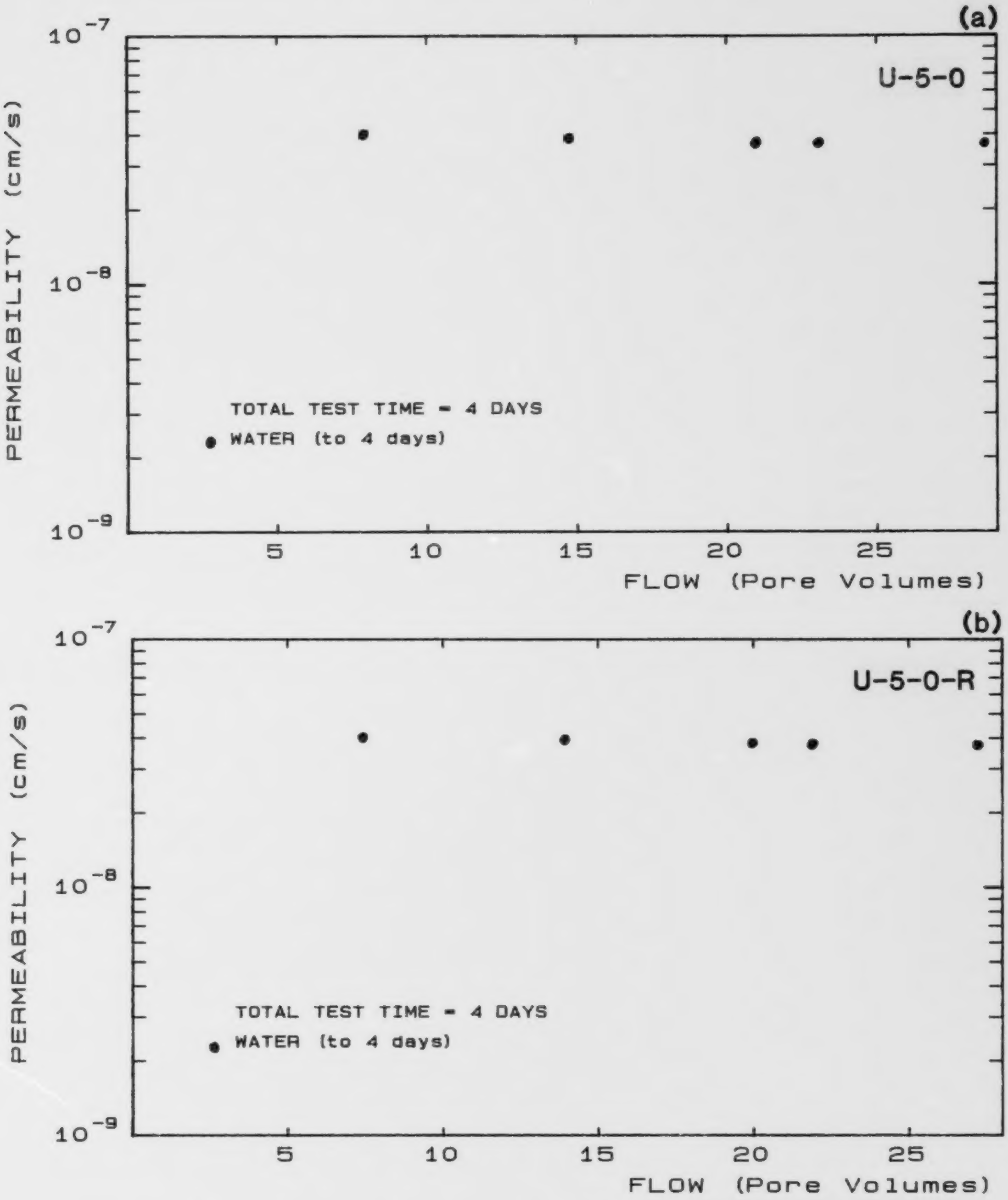
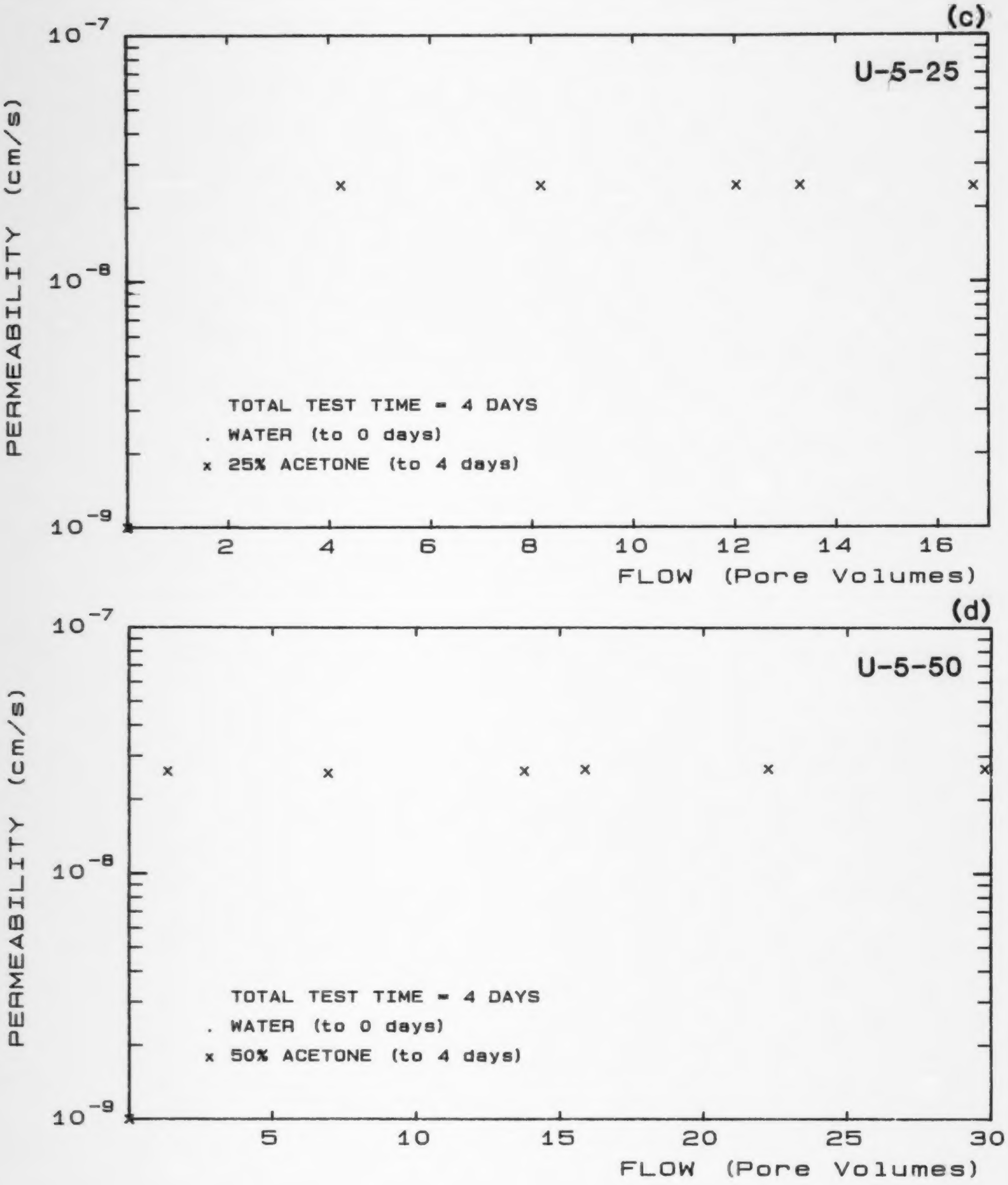


Figure C-2: Hydraulic conductivity of filter cake formed from 5% slurry of unaltered bentonite no. 1.



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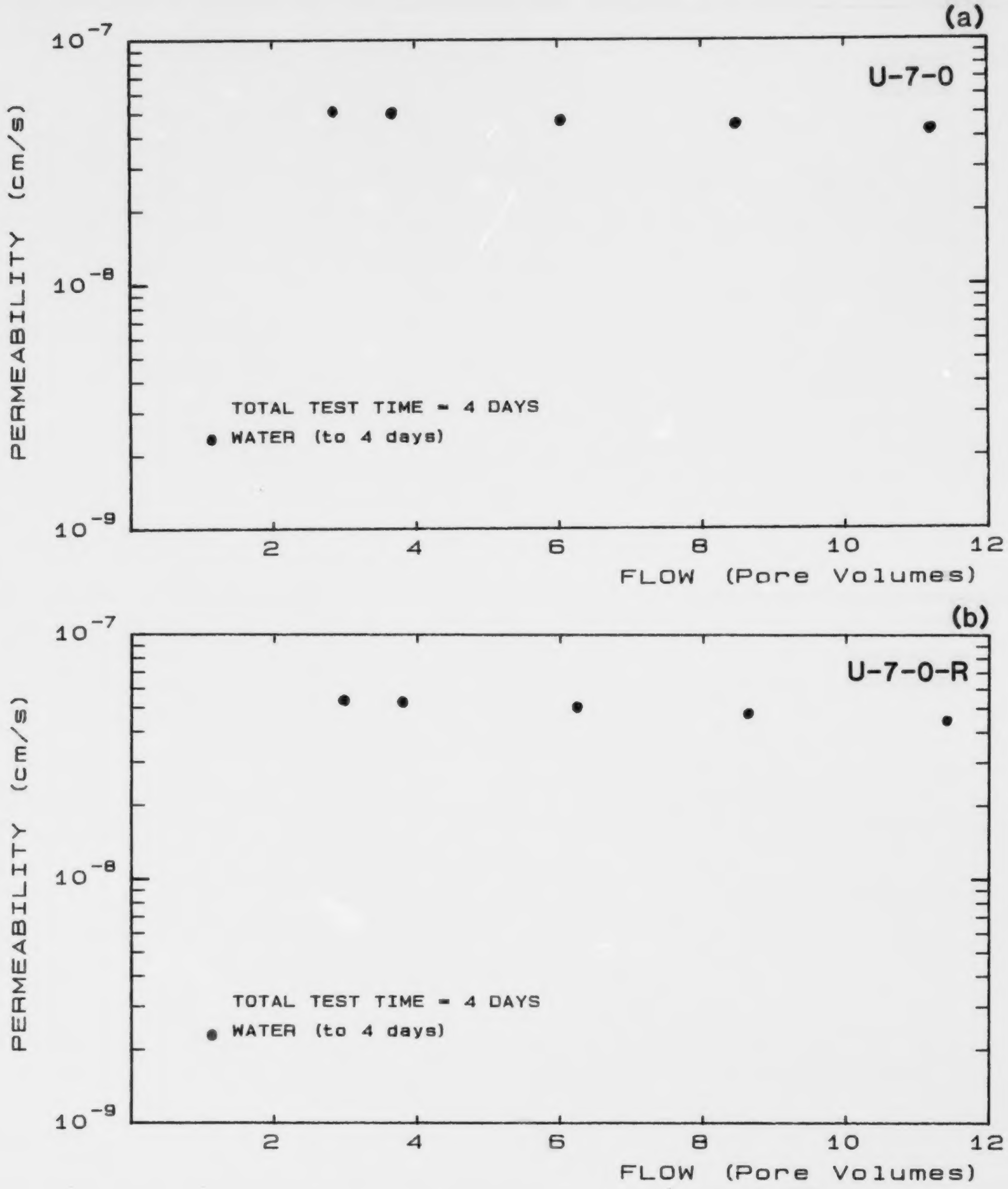
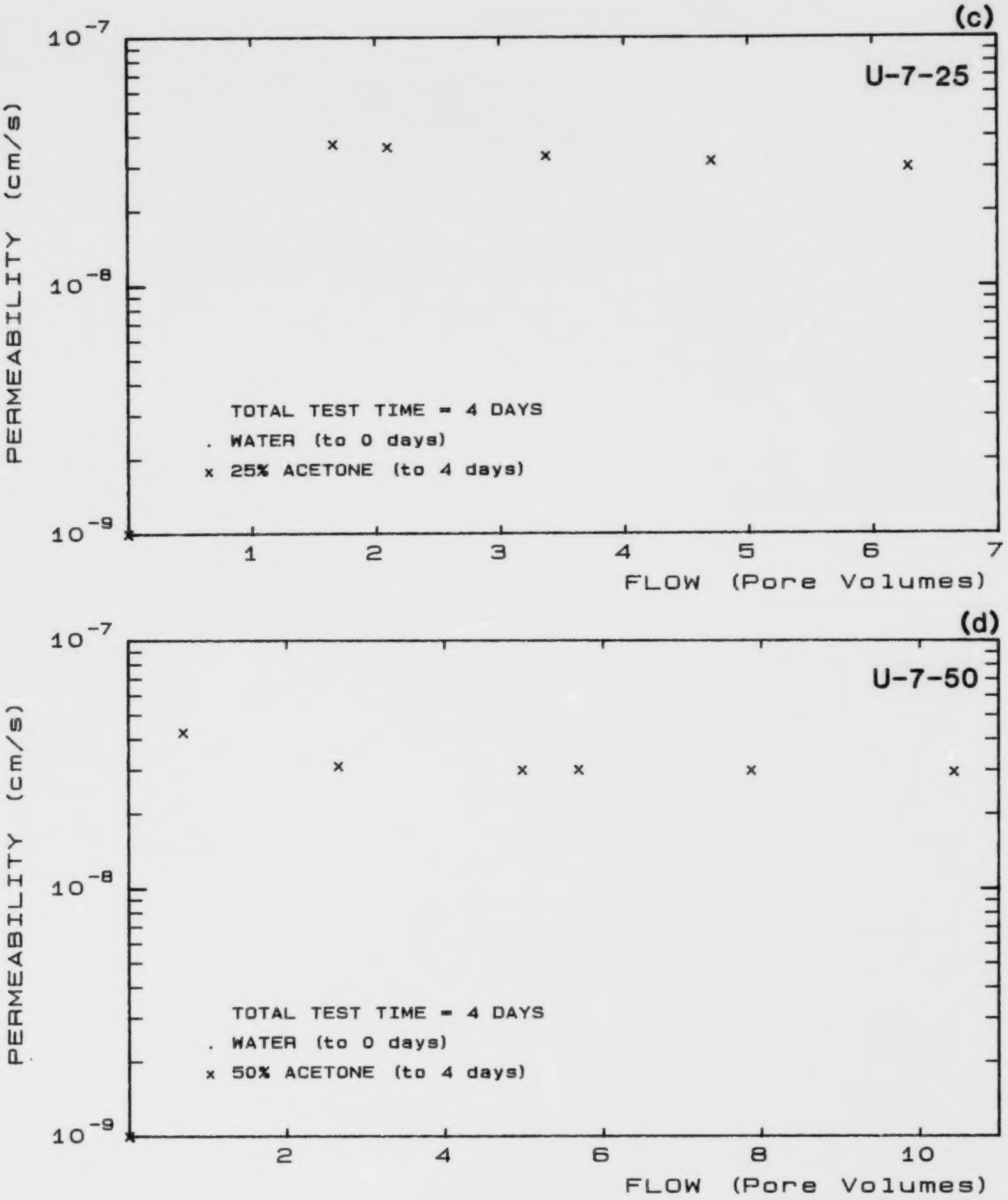


Figure C-3: Hydraulic conductivity of filter cake formed from 7% slurry of unaltered bentonite no. 1.



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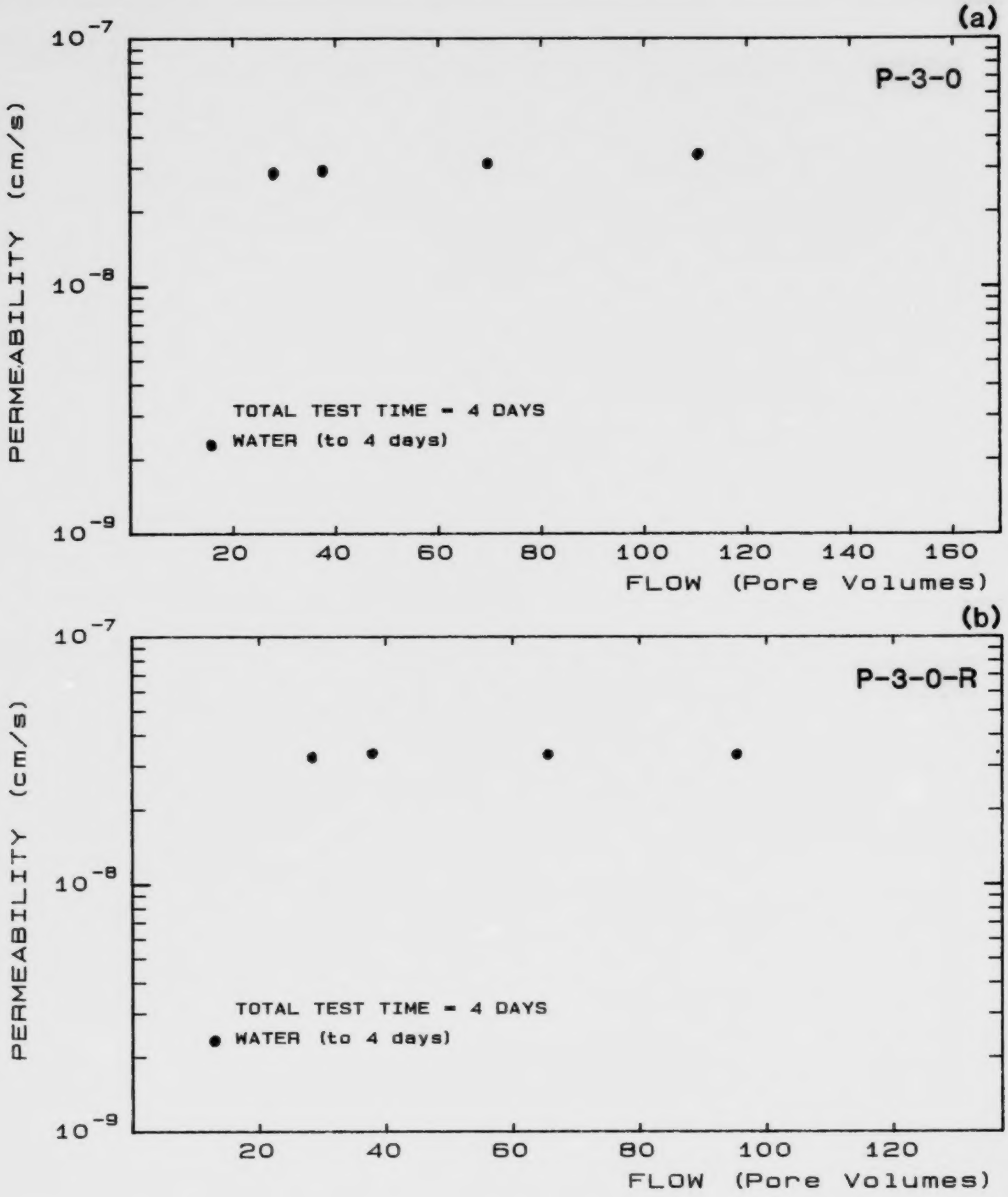
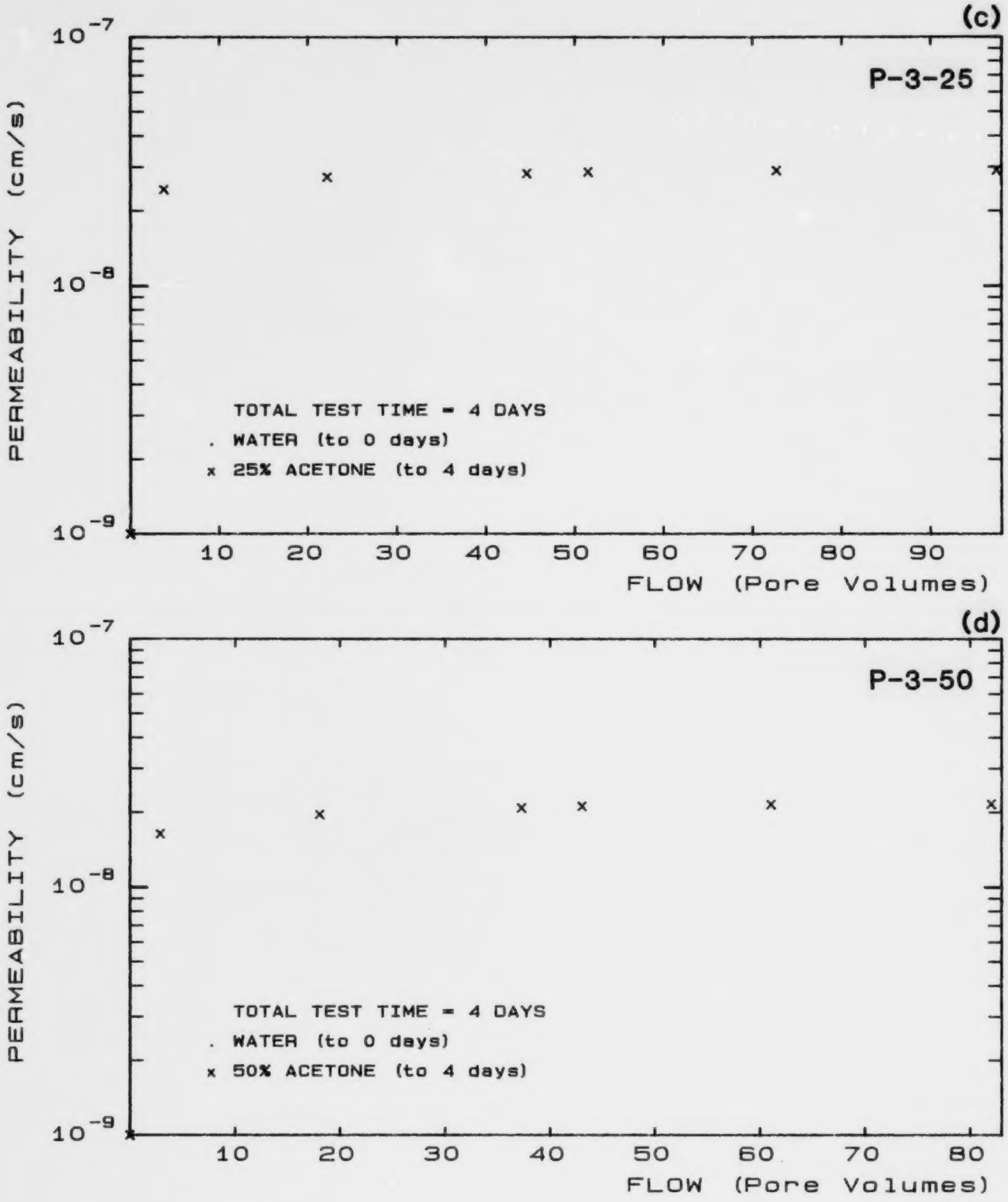


Figure C-4: Hydraulic conductivity of filter cake formed from 3% slurry of polymer protected bentonite no. 3.



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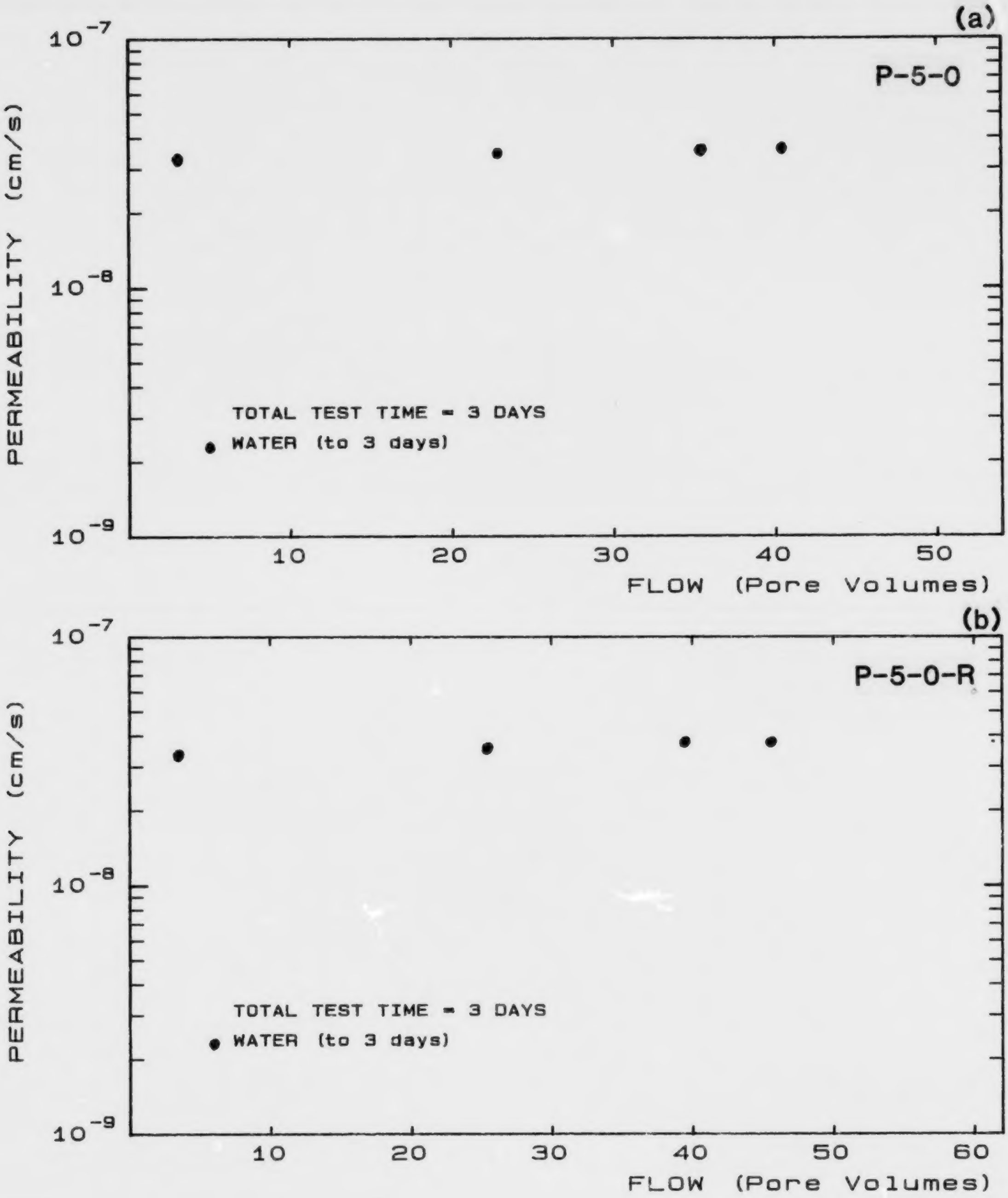
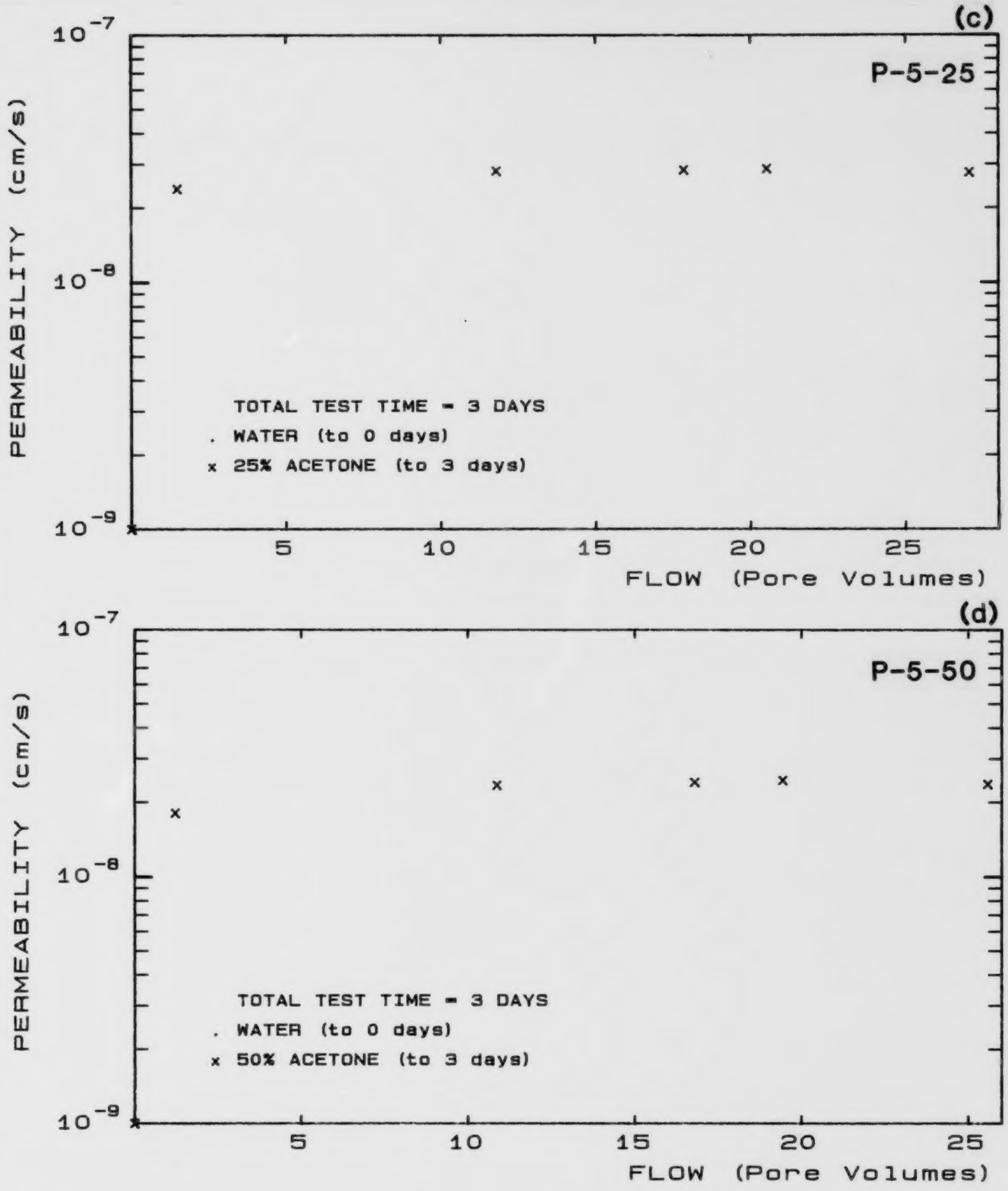


Figure C-5: Hydraulic conductivity of filter cake formed from 5% slurry of polymer protected bentonite no. 3.



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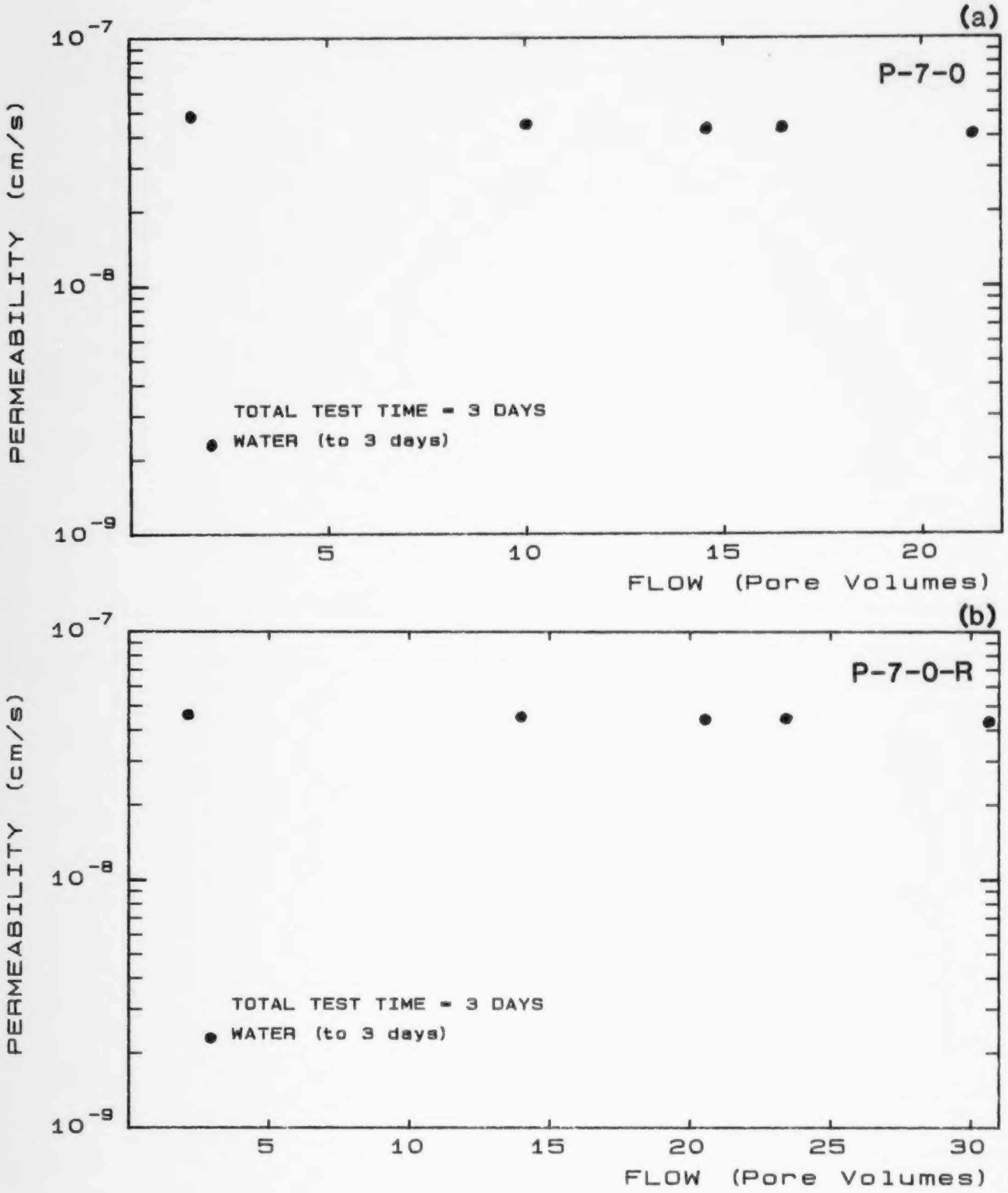
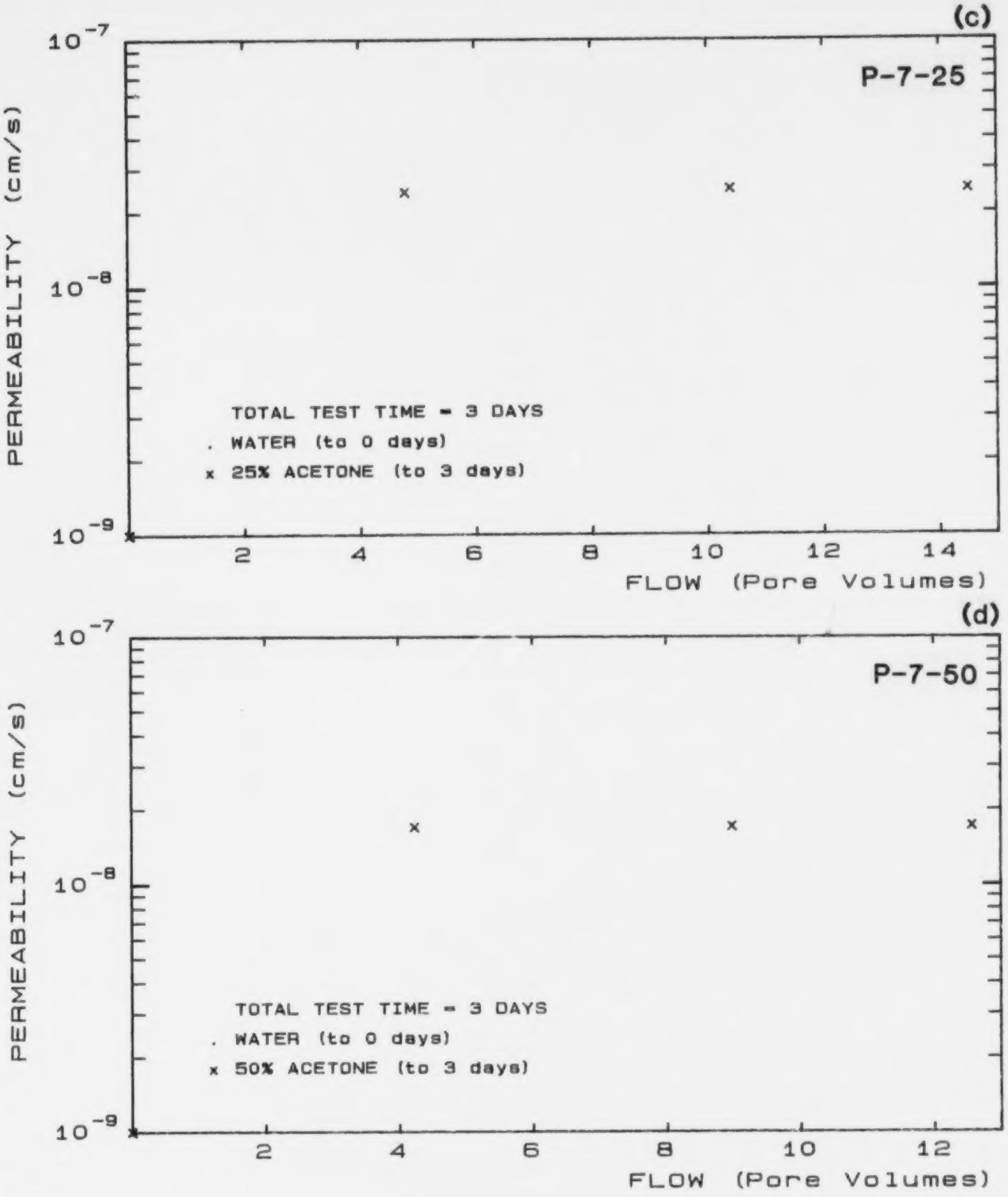


Figure C-6: Hydraulic conductivity of filter cake formed from 7% slurry of polymer protected bentonite no. 3.



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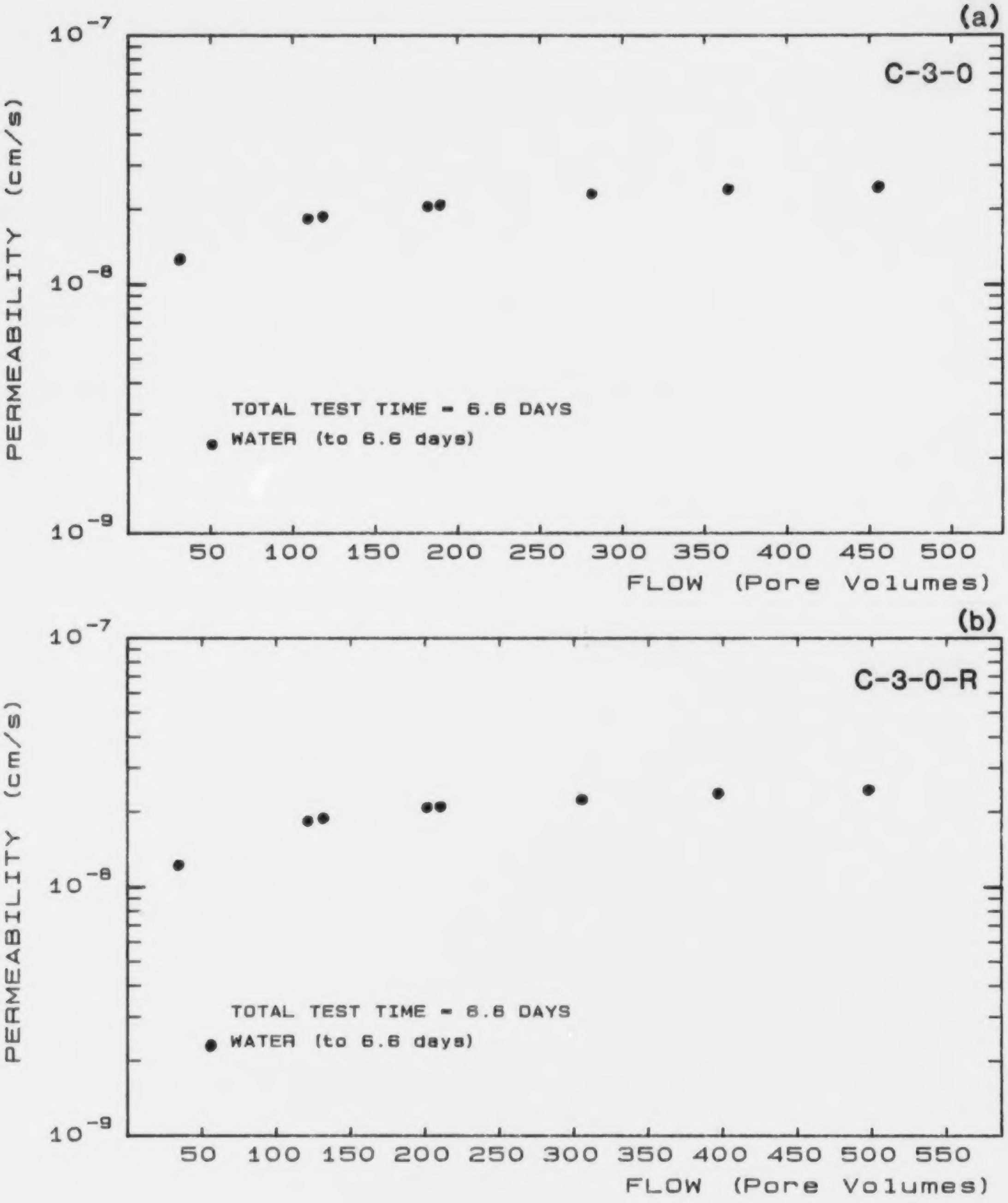
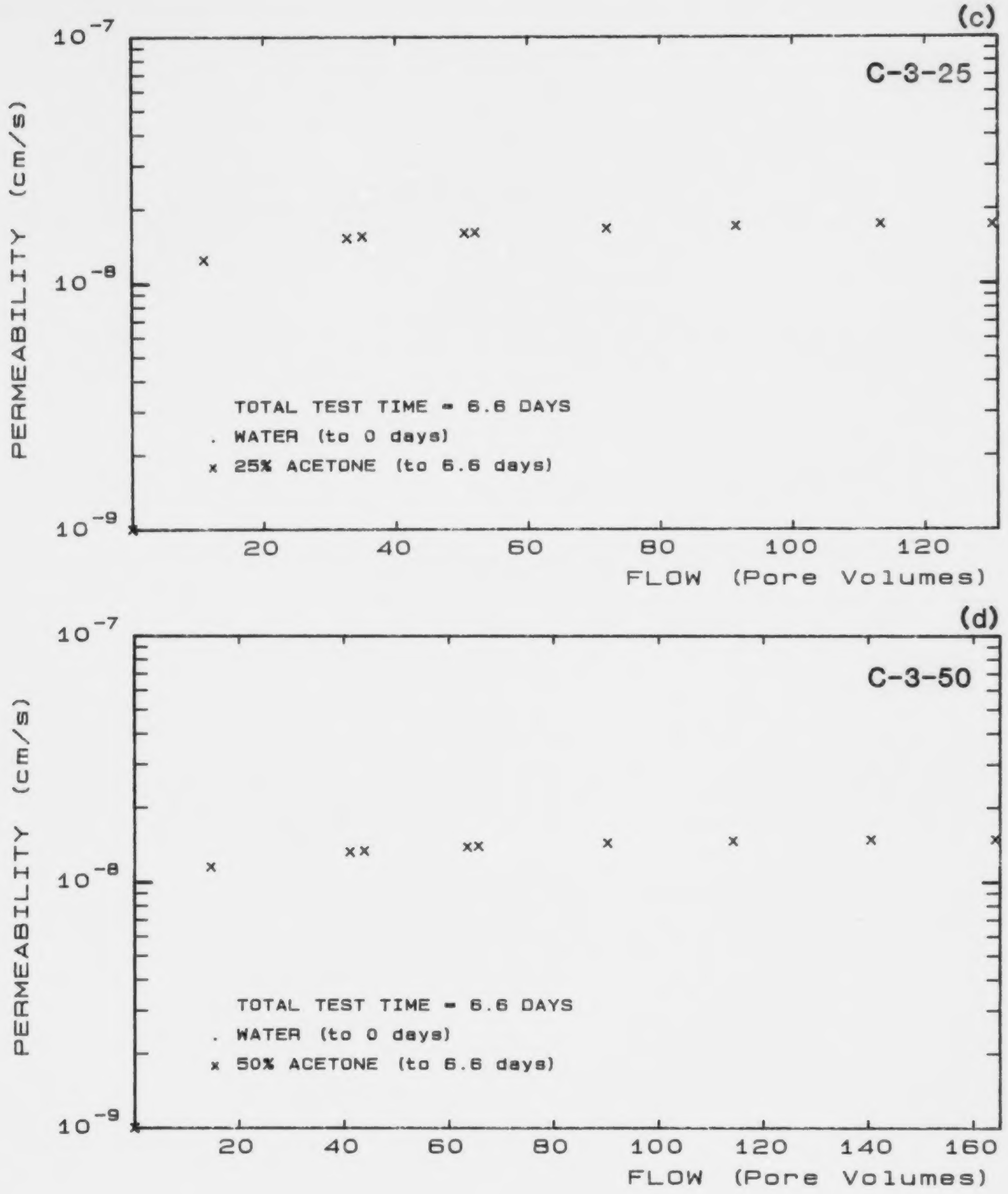


Figure C-7: Hydraulic conductivity of filter cake formed from 3% slurry of chemically treated bentonite no. 6.



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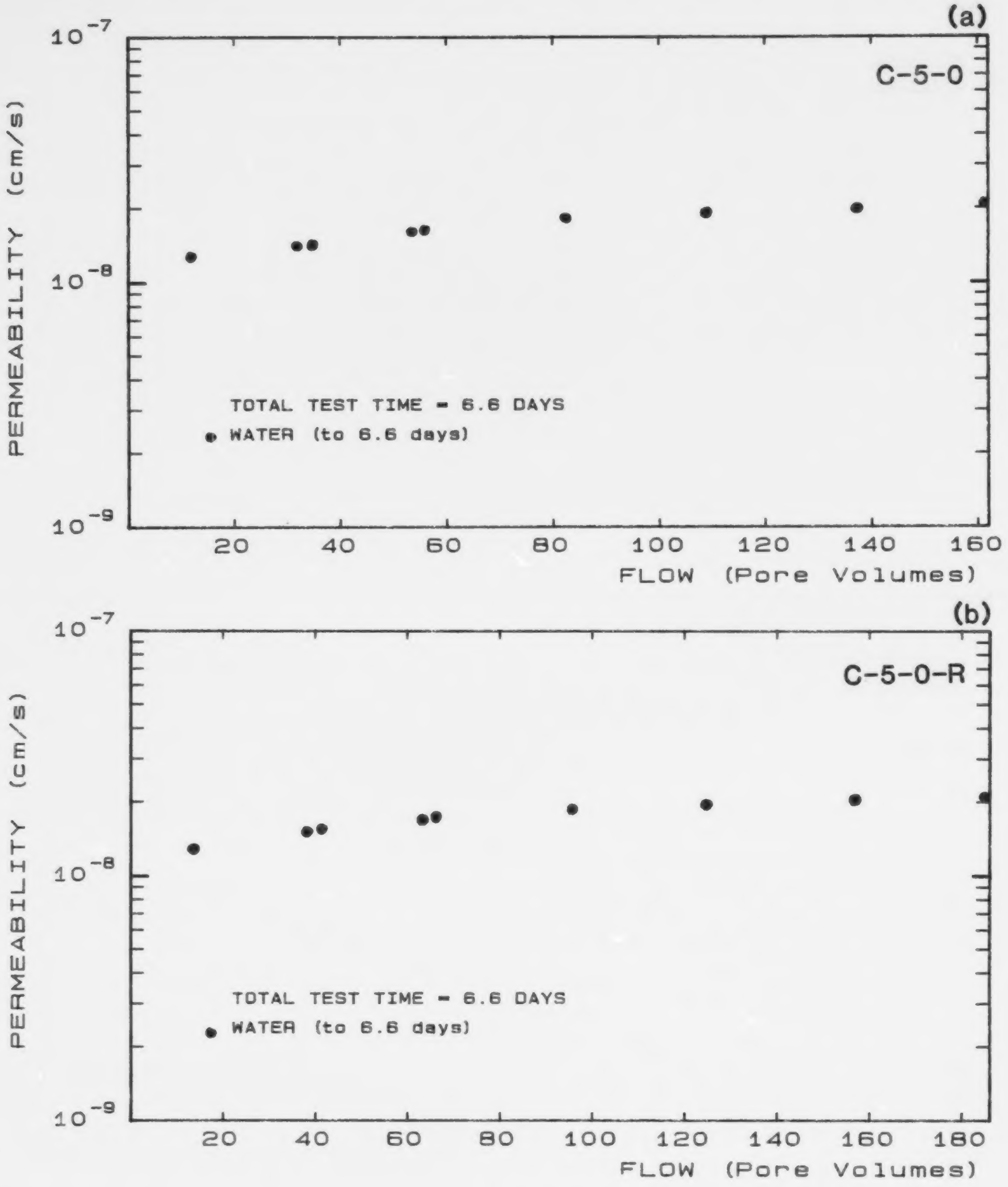
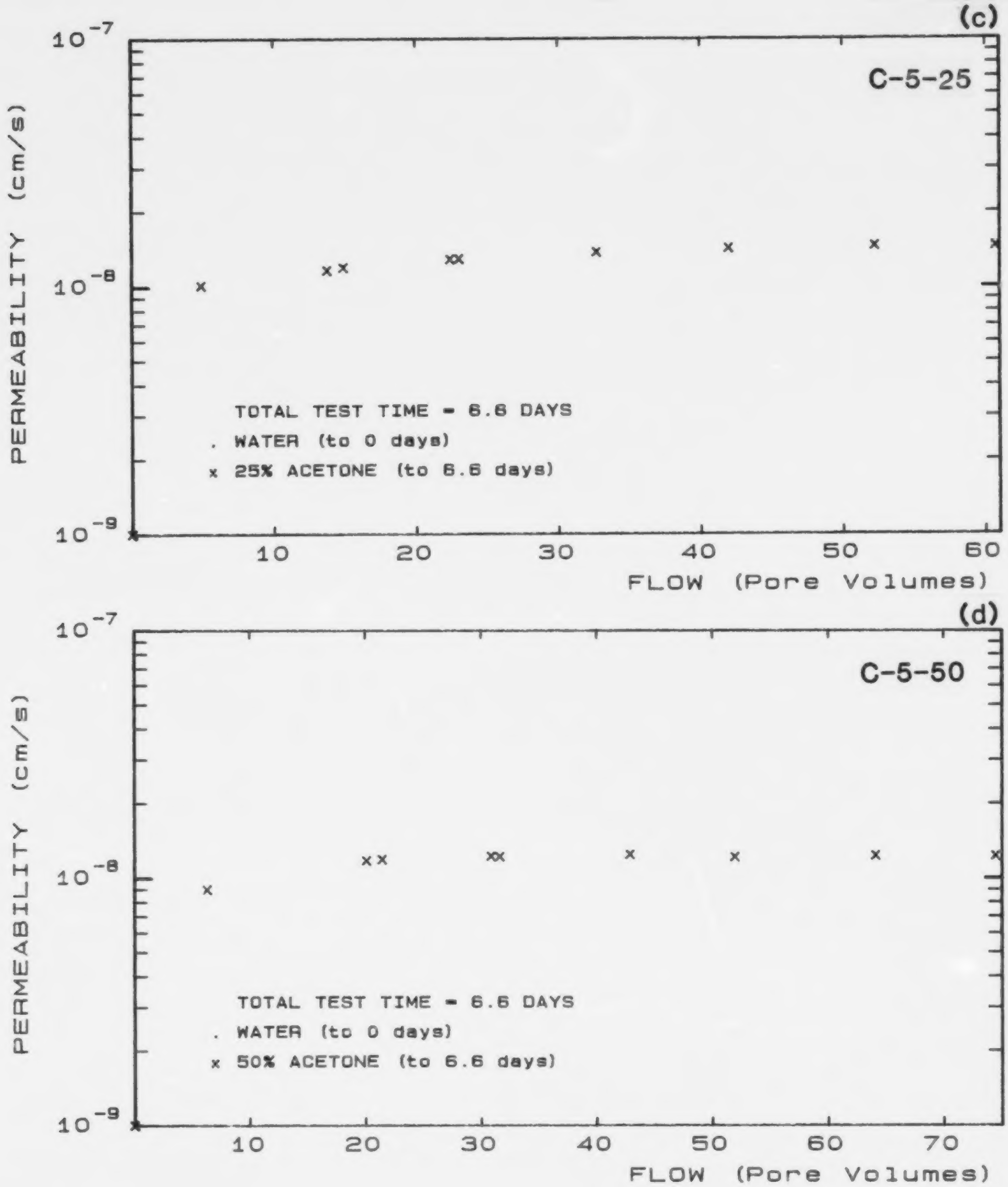


Figure C-8: Hydraulic conductivity of filter cake formed from 5% slurry of chemically treated bentonite no. 6.



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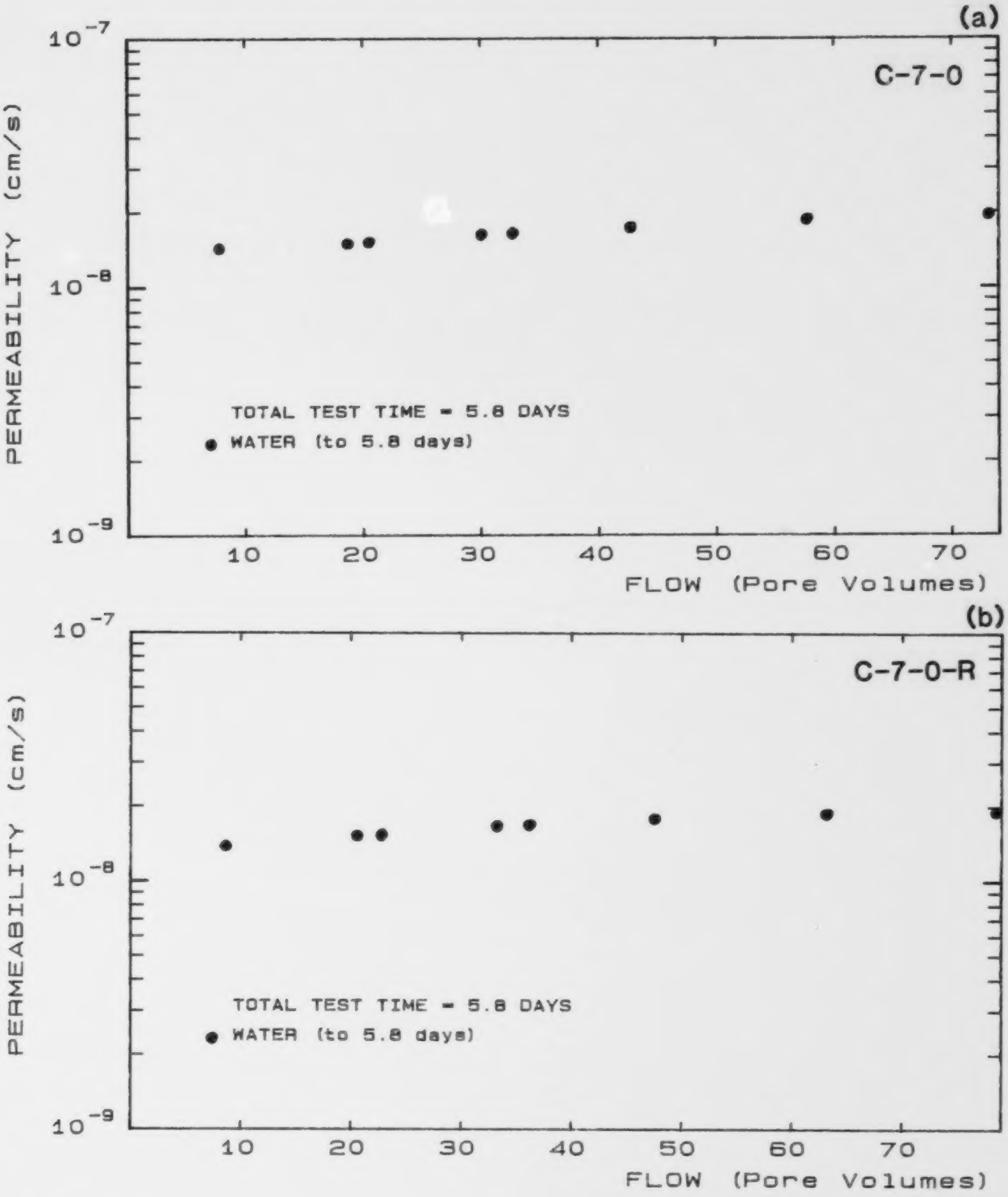


Figure C-9: Hydraulic conductivity of filter cake formed from 7% slurry of chemically treated bentonite no. 6.

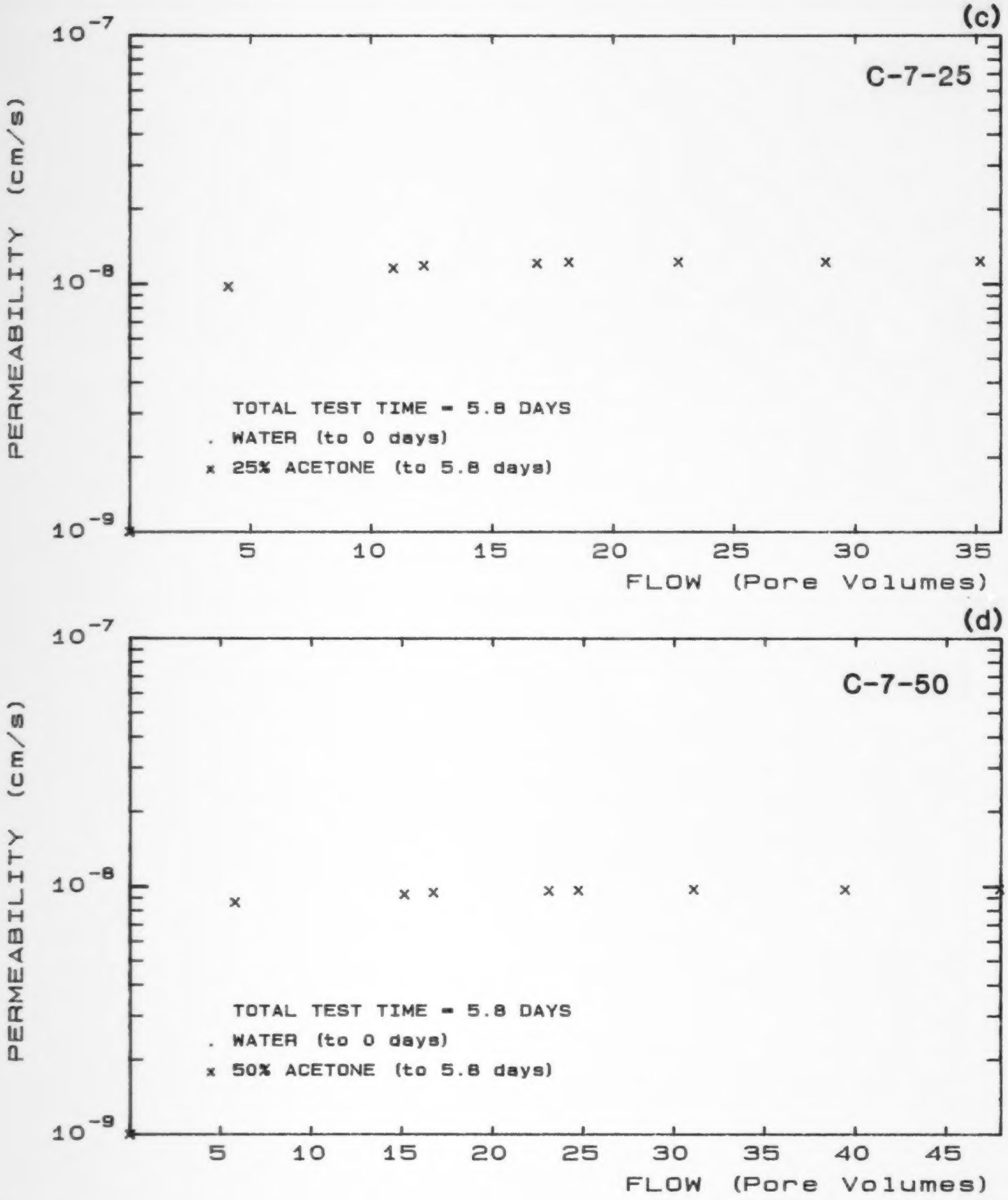


Figure C-9. (continued)

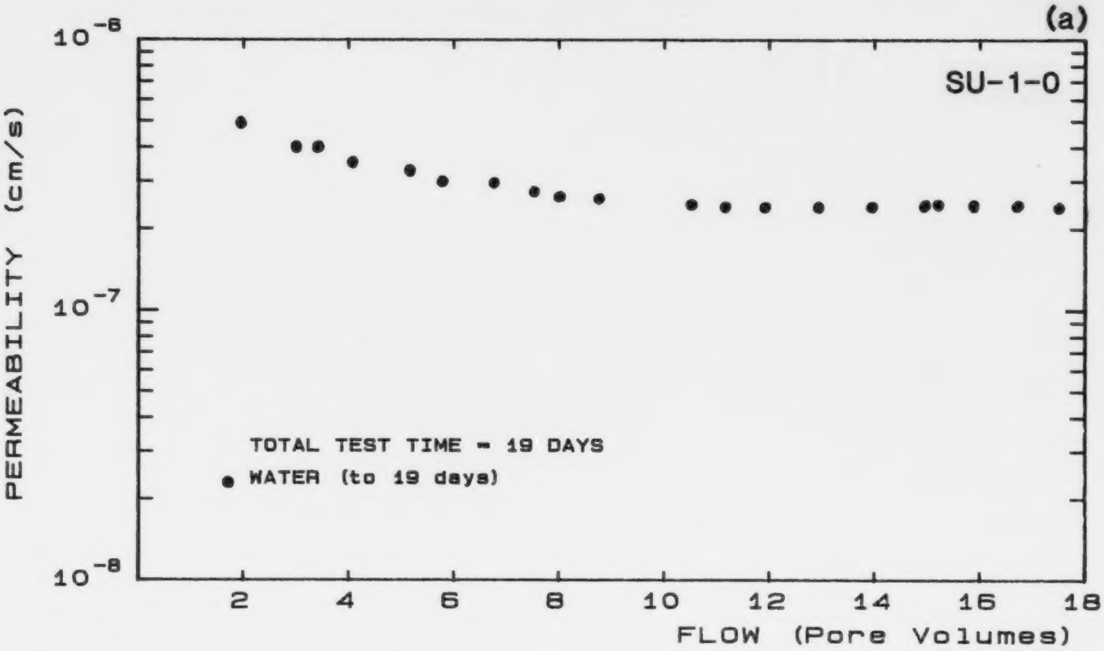
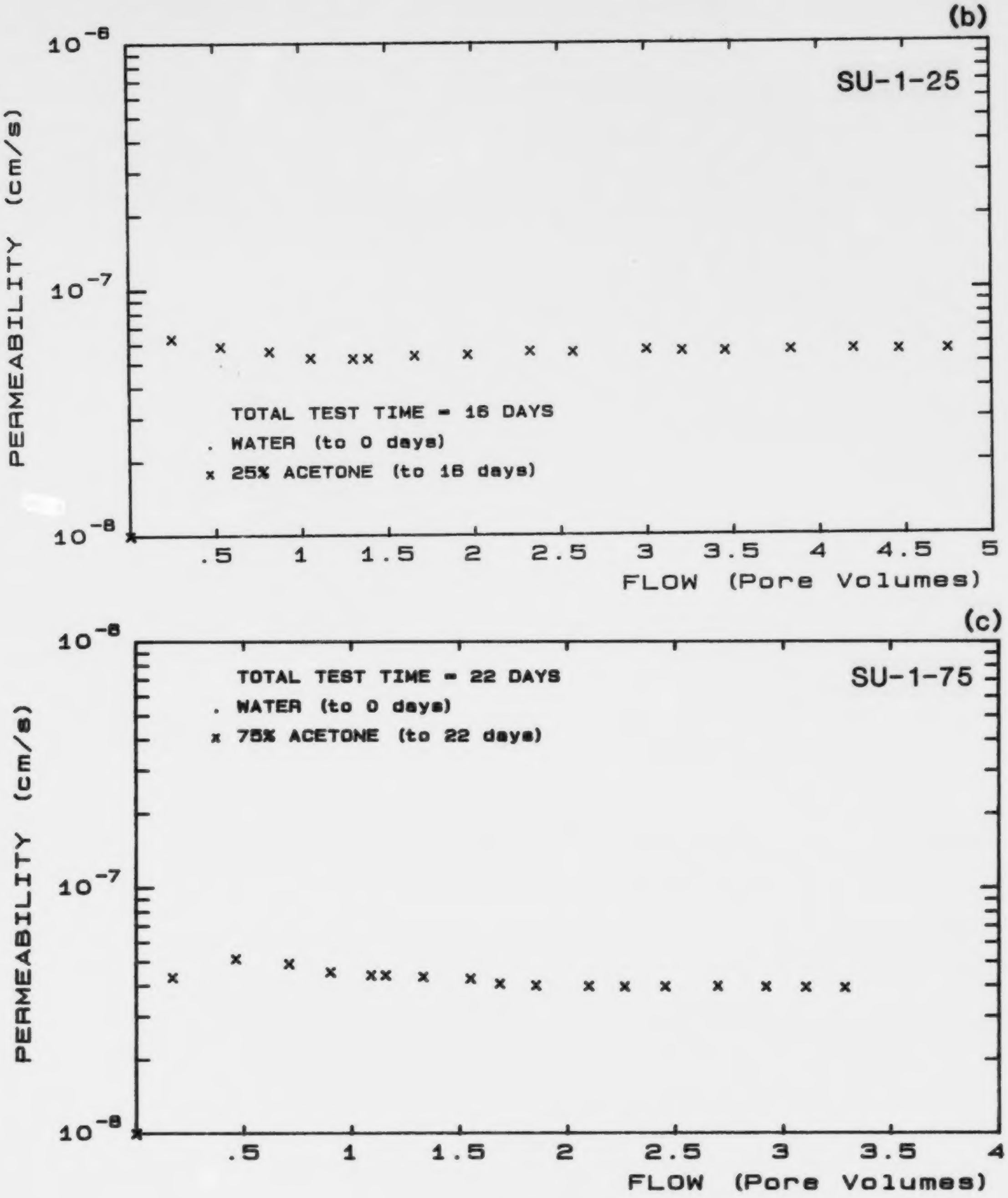


Figure C-10: Hydraulic conductivity of soil-bentonite using 1% unaltered bentonite no. 1.



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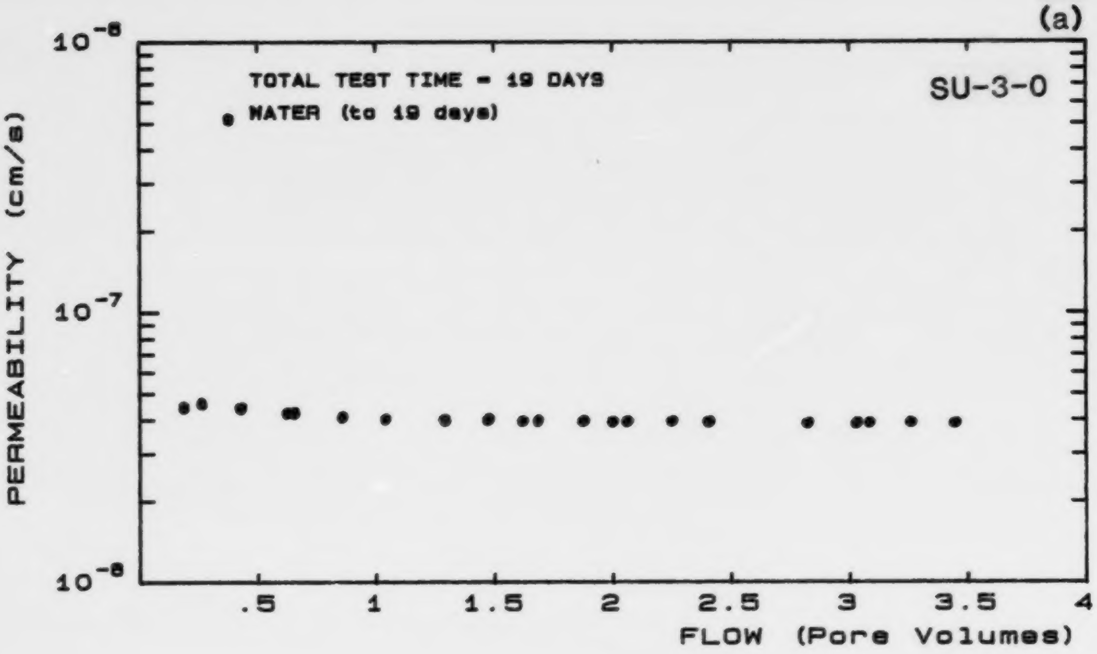


Figure C-11: Hydraulic conductivity of soil-bentonite using 3% unaltered bentonite no. 1.

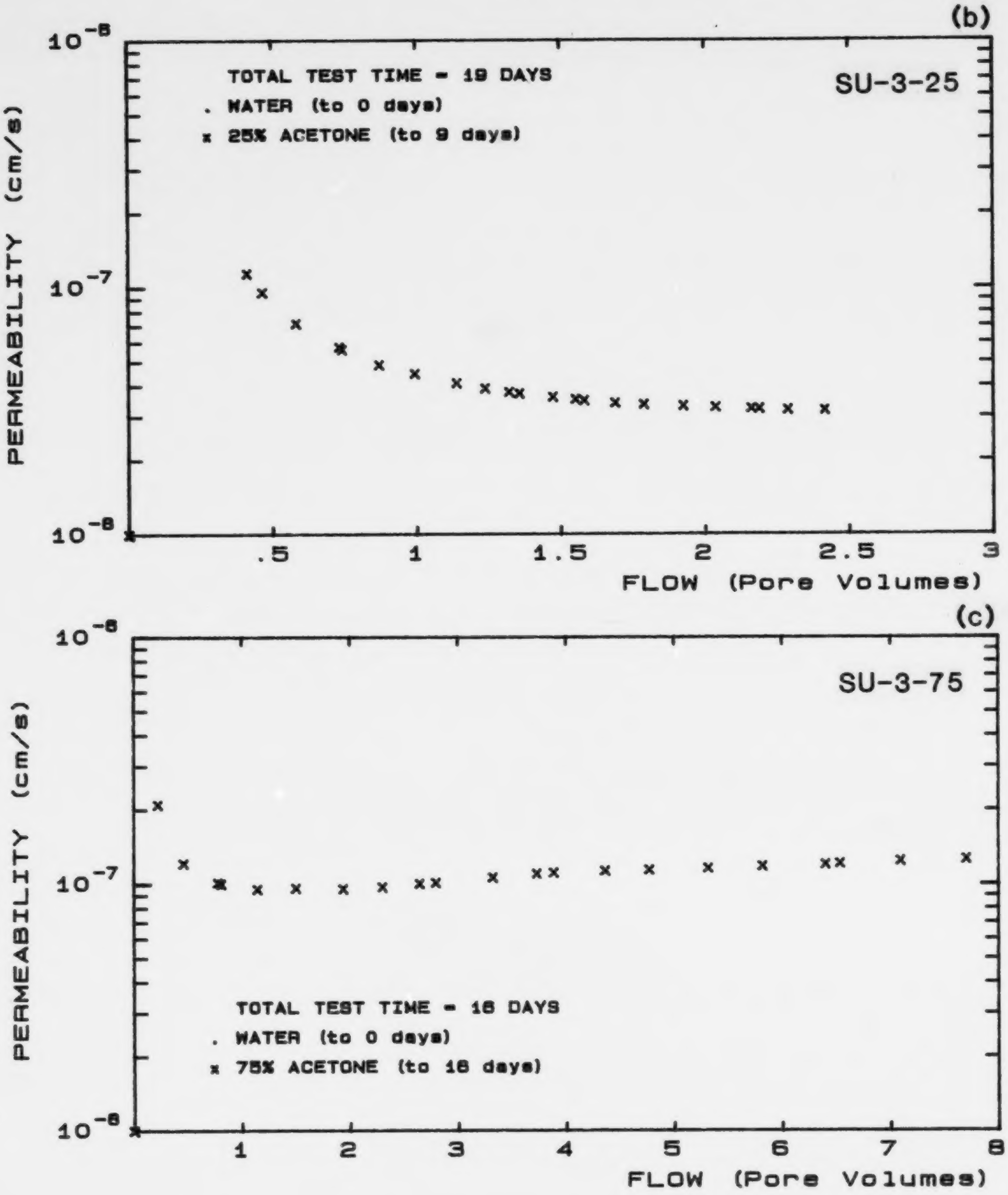


Figure C-11. (continued)

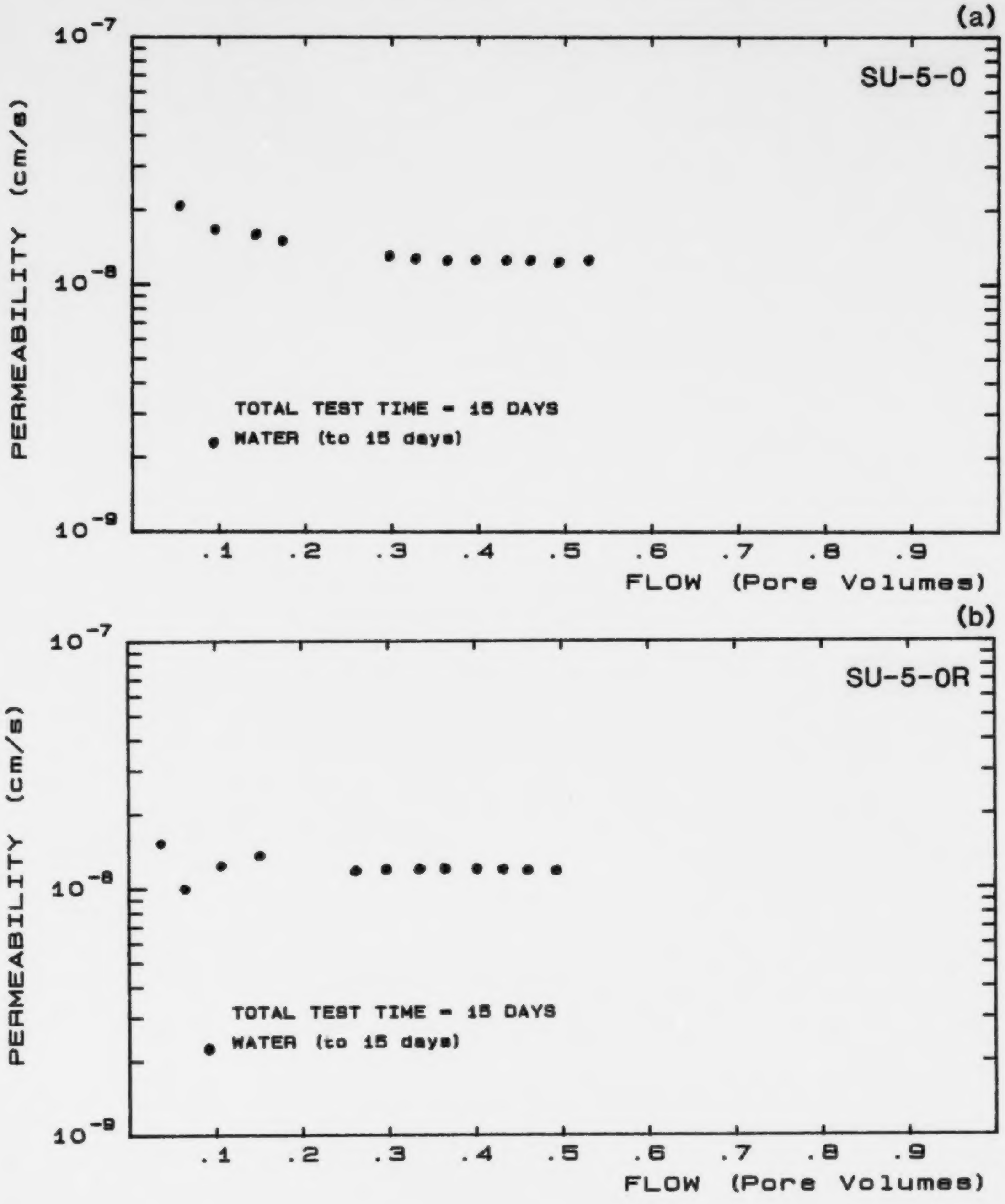
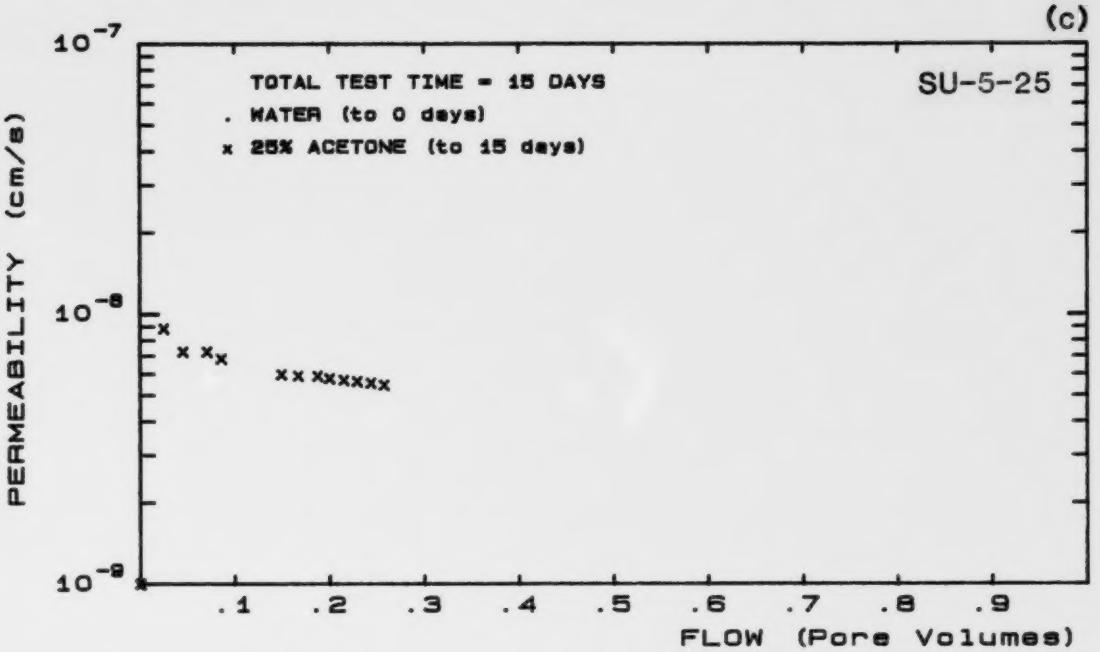
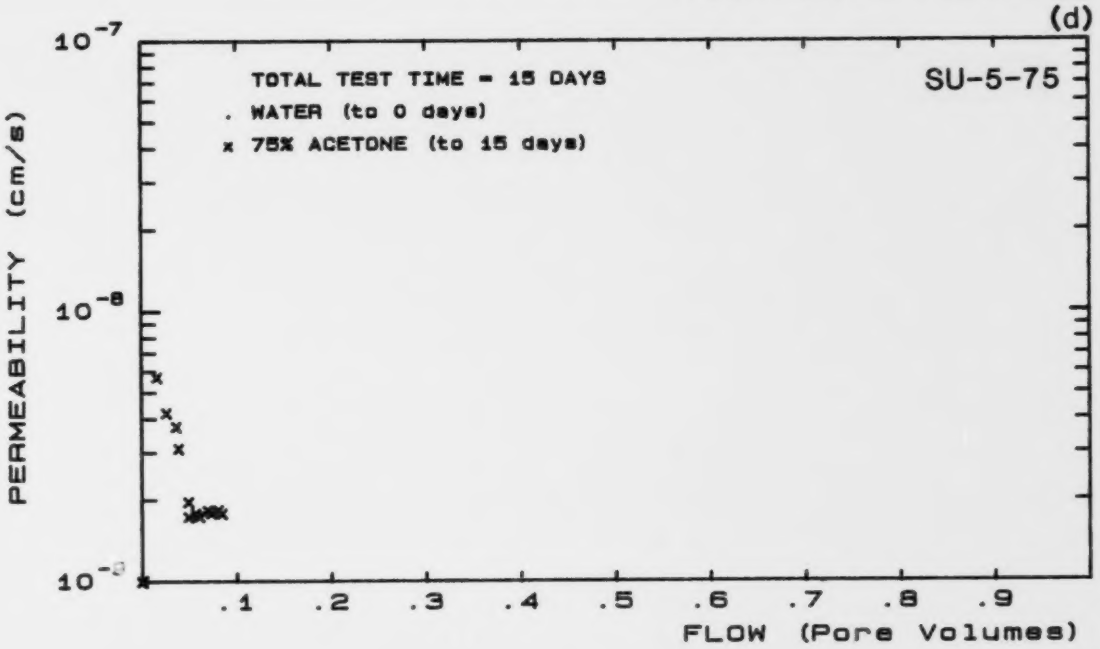


Figure C-12: Hydraulic conductivity of soil-bentonite using 5% unaltered bentonite no. 1.





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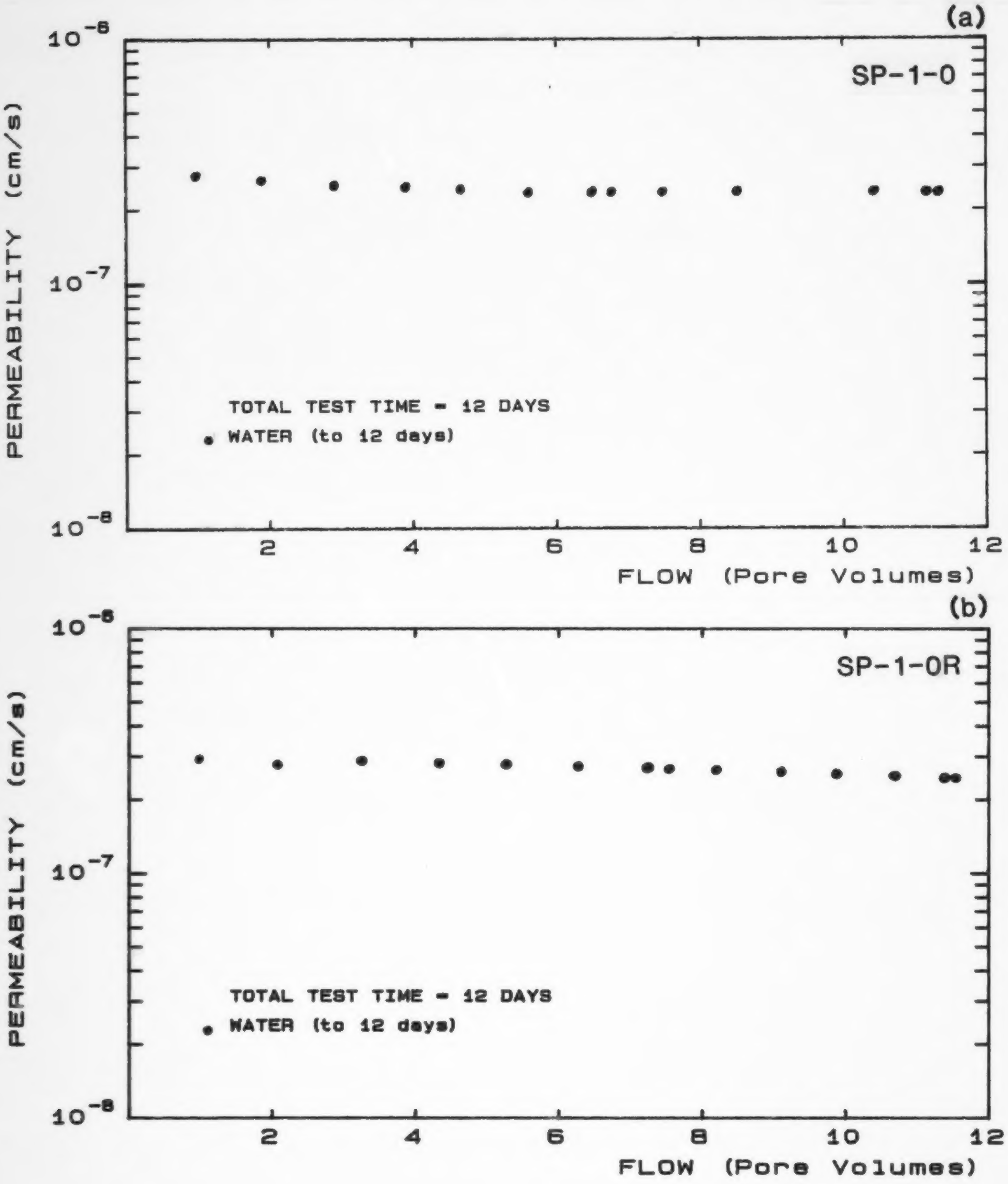
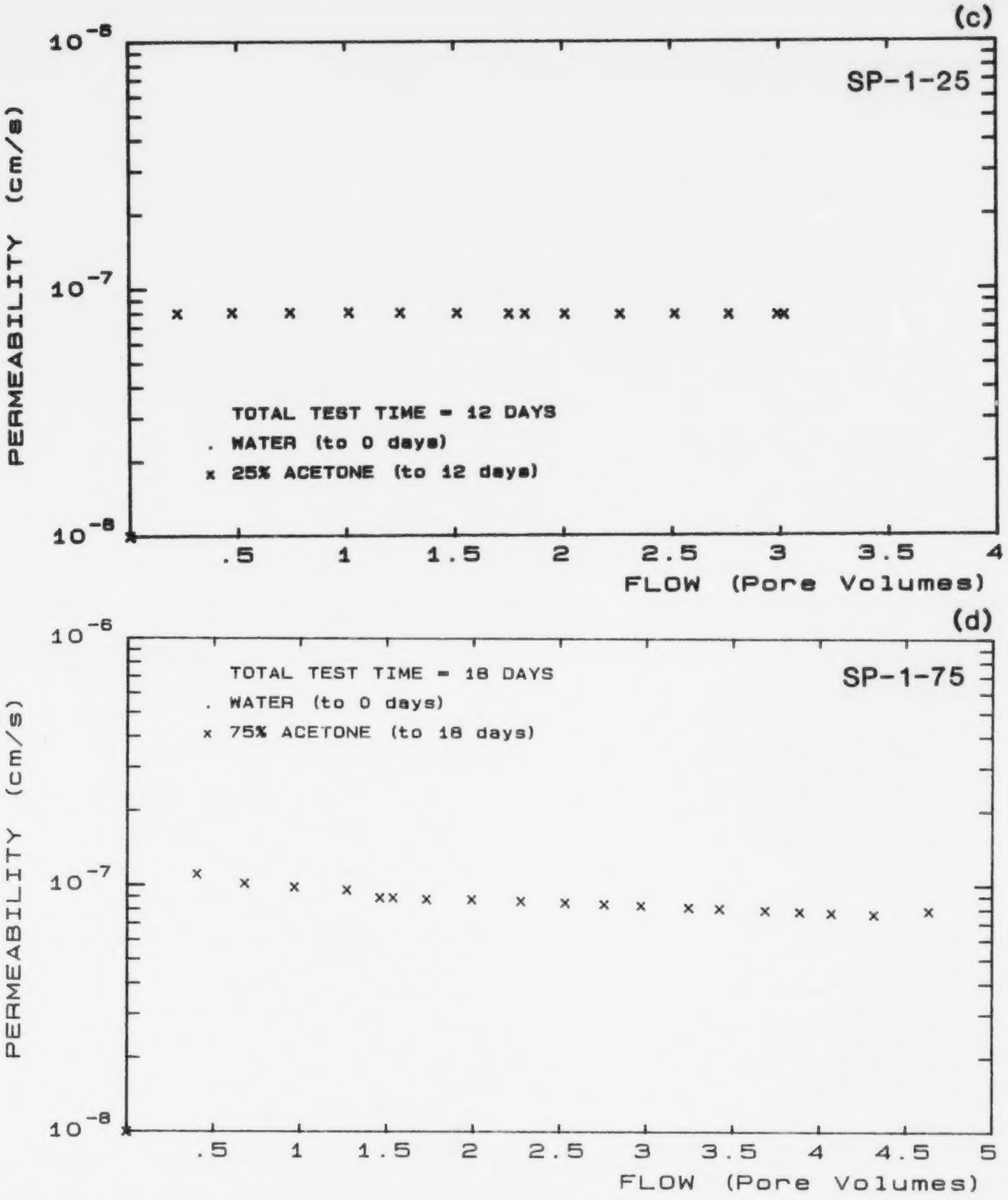


Figure C-13: Hydraulic conductivity of soil-bentonite using 1% polymer protected bentonite no. 3.



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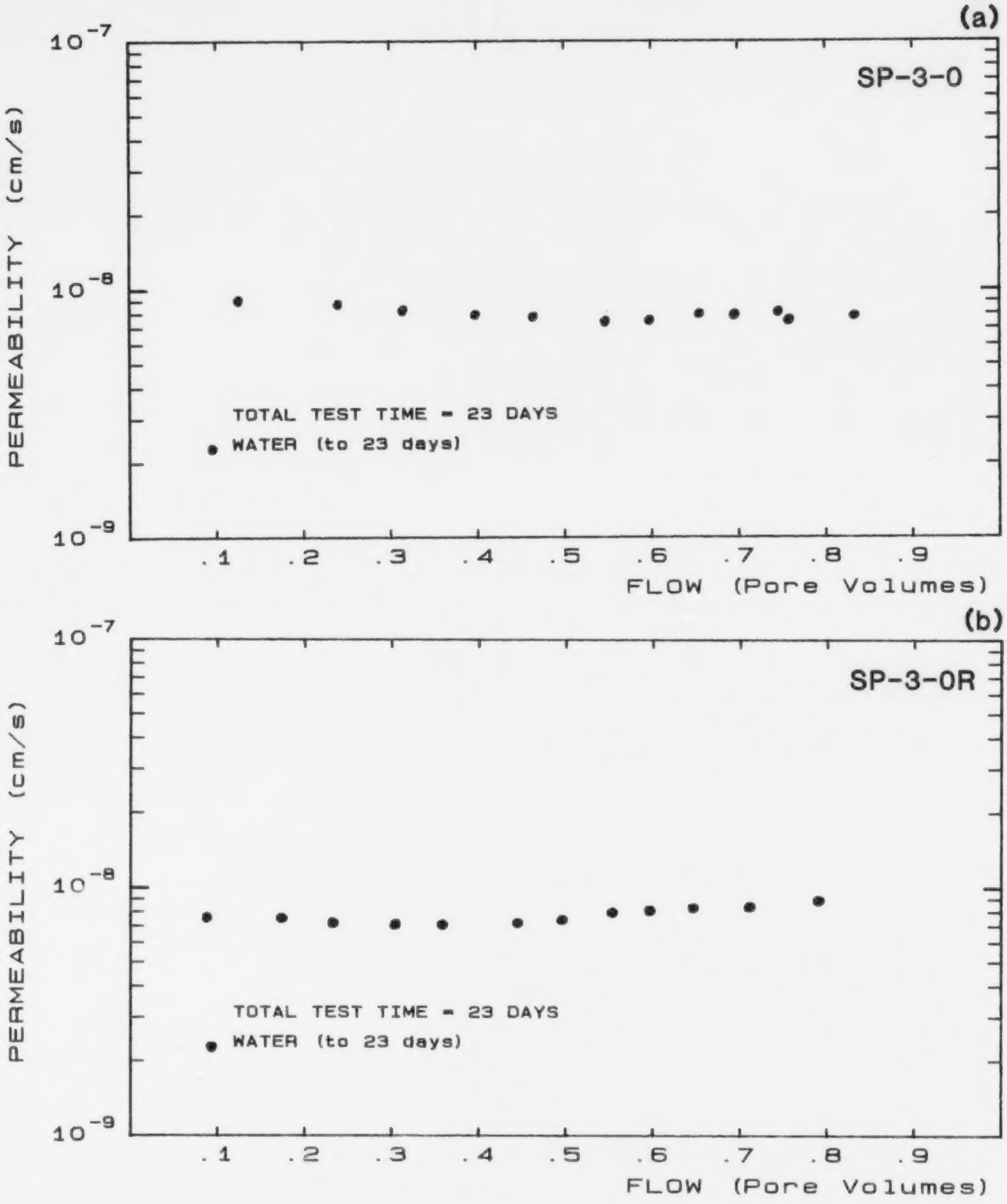
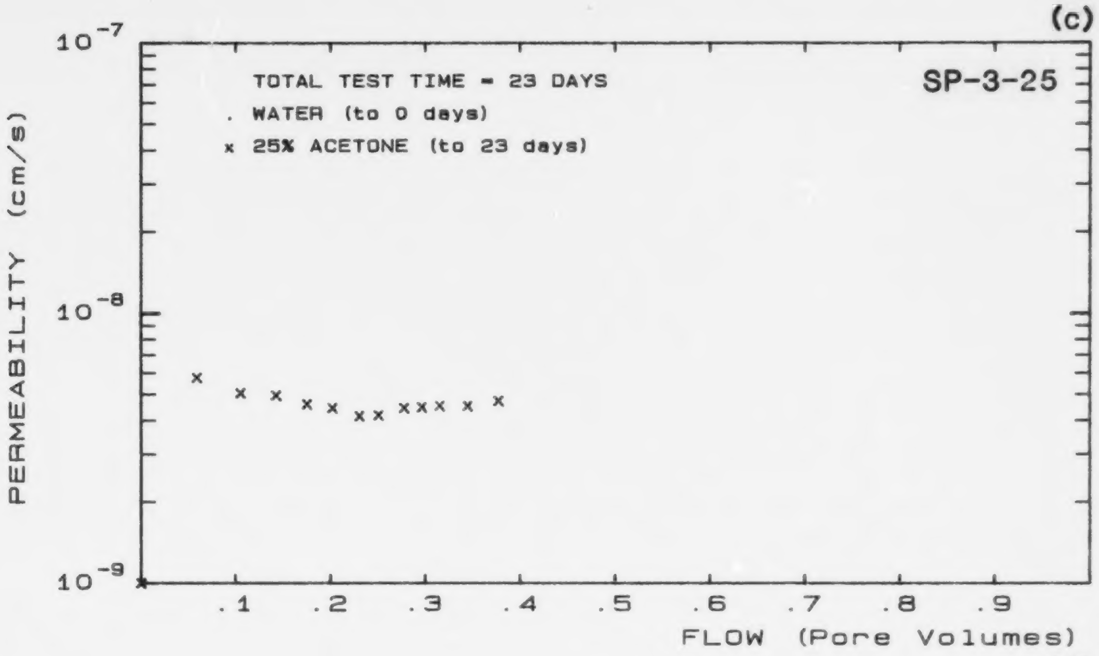
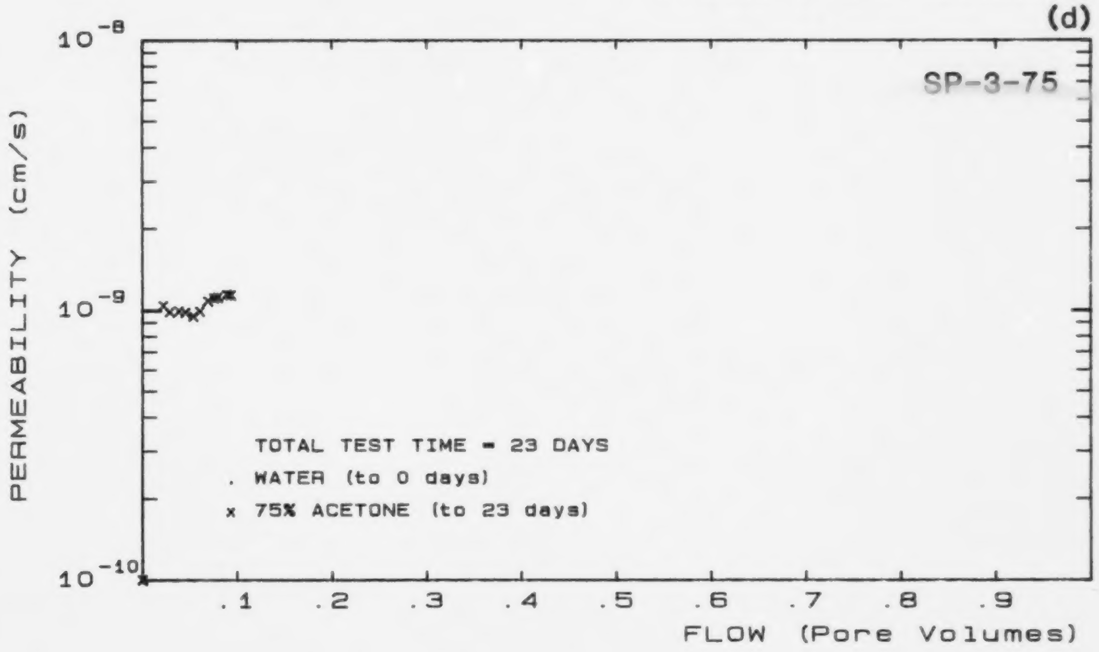


Figure C-14: Hydraulic conductivity of soil-bentonite using 3% polymer protected bentonite no. 3.





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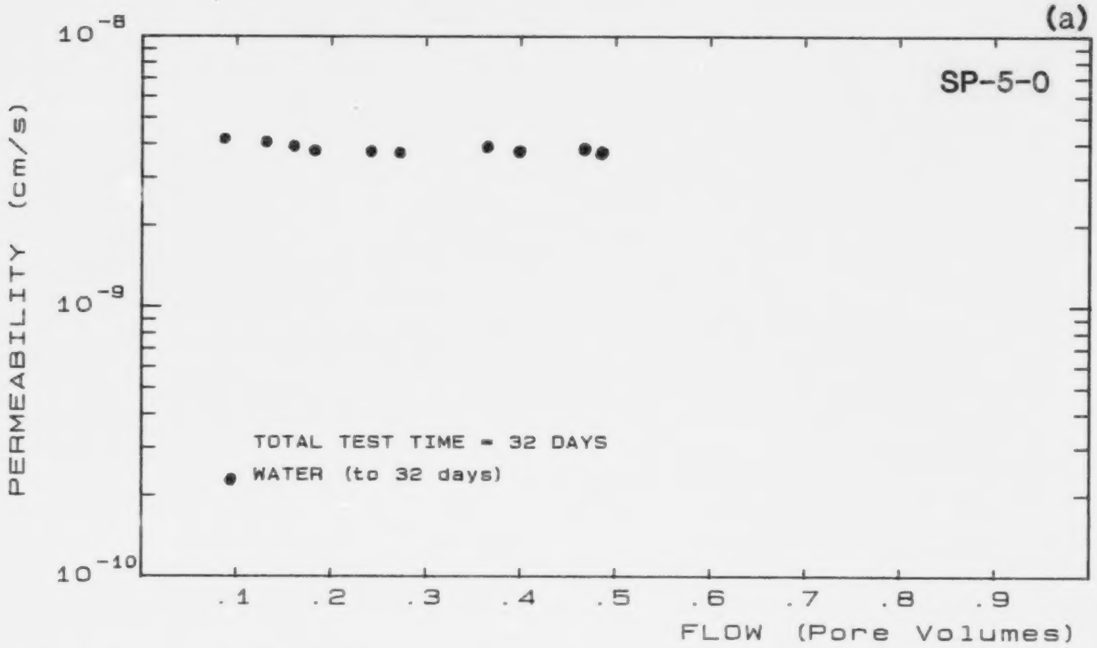
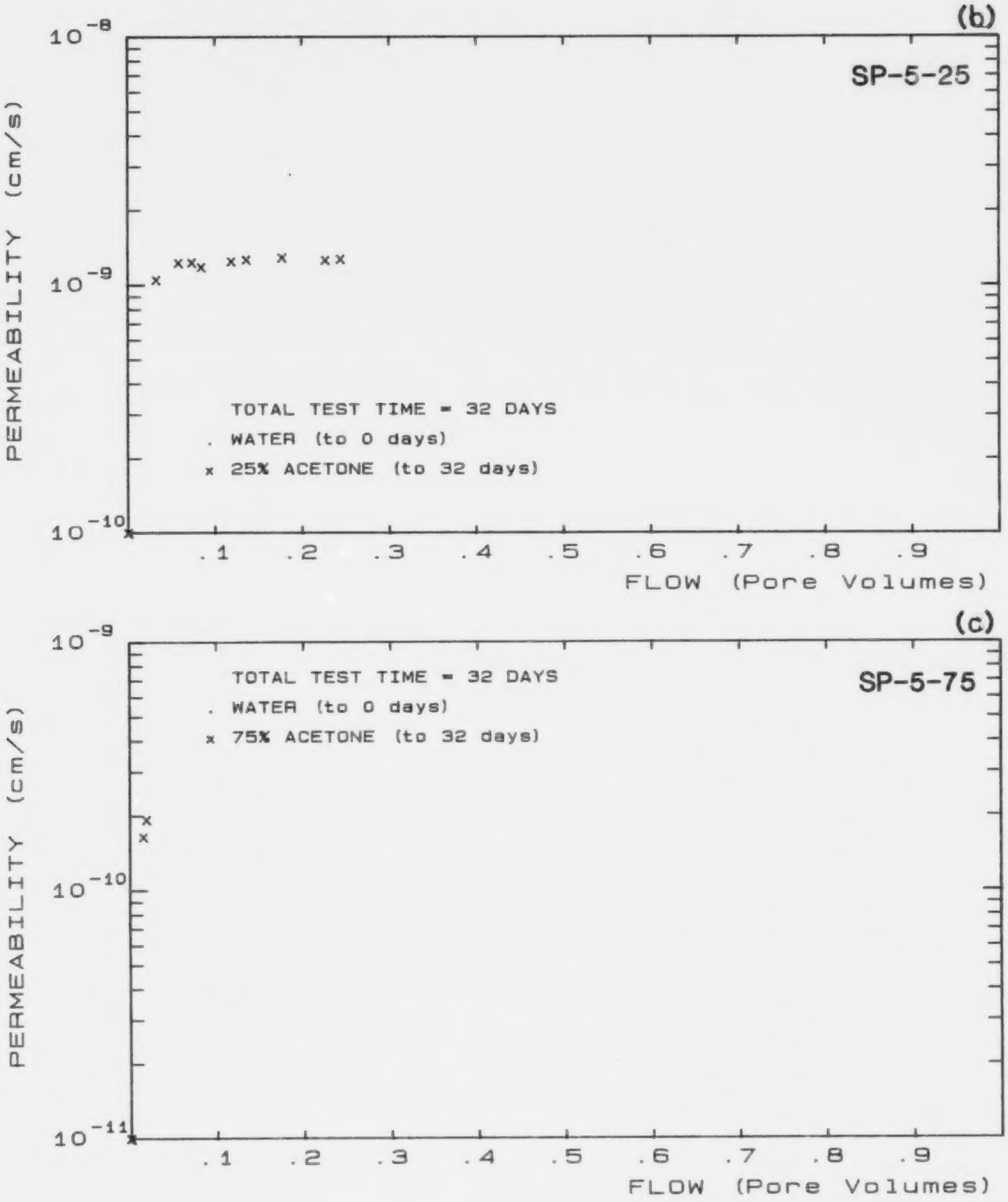


Figure C-15: Hydraulic conductivity of soil-bentonite using 5% polymer protected bentonite no. 3.



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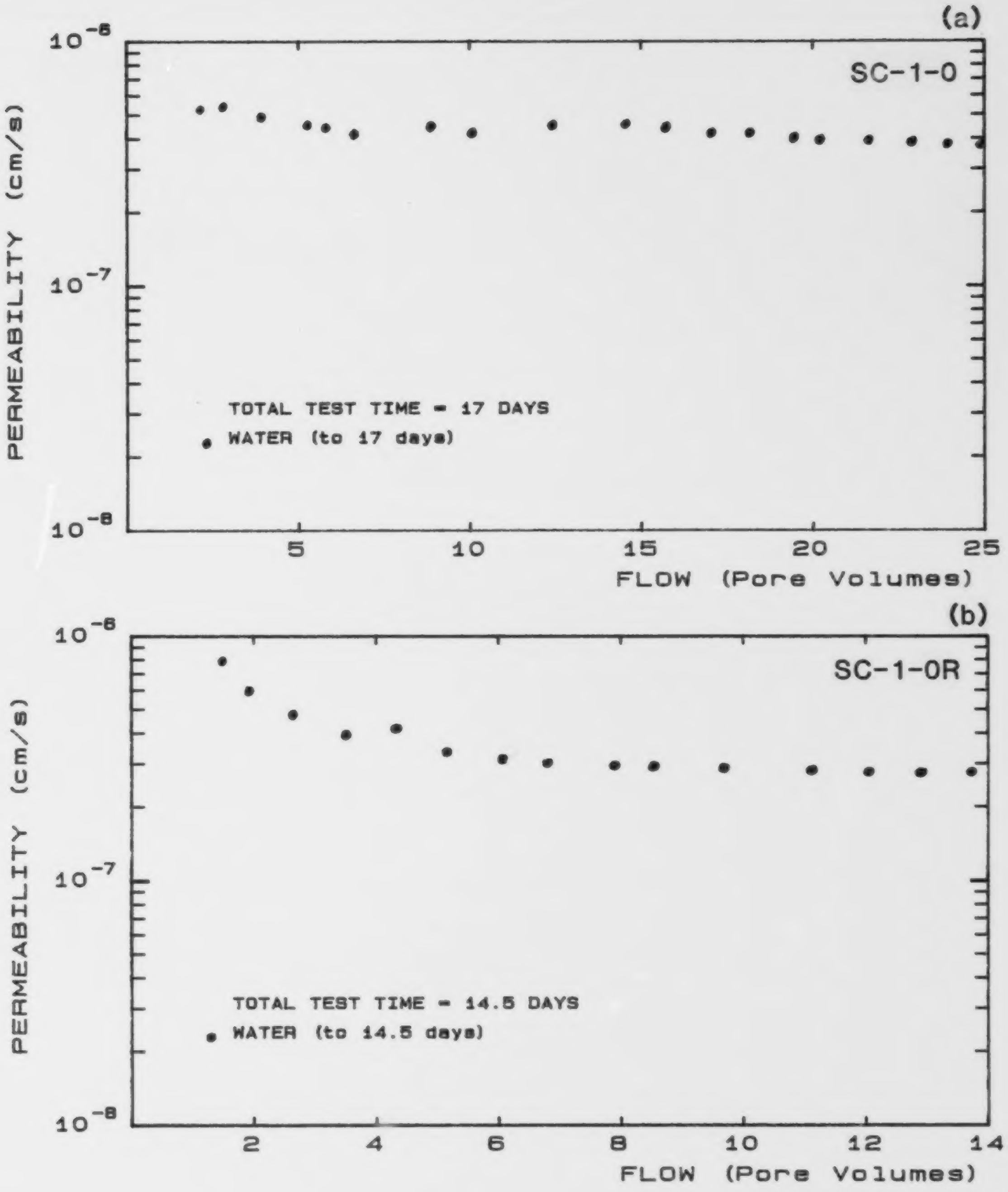
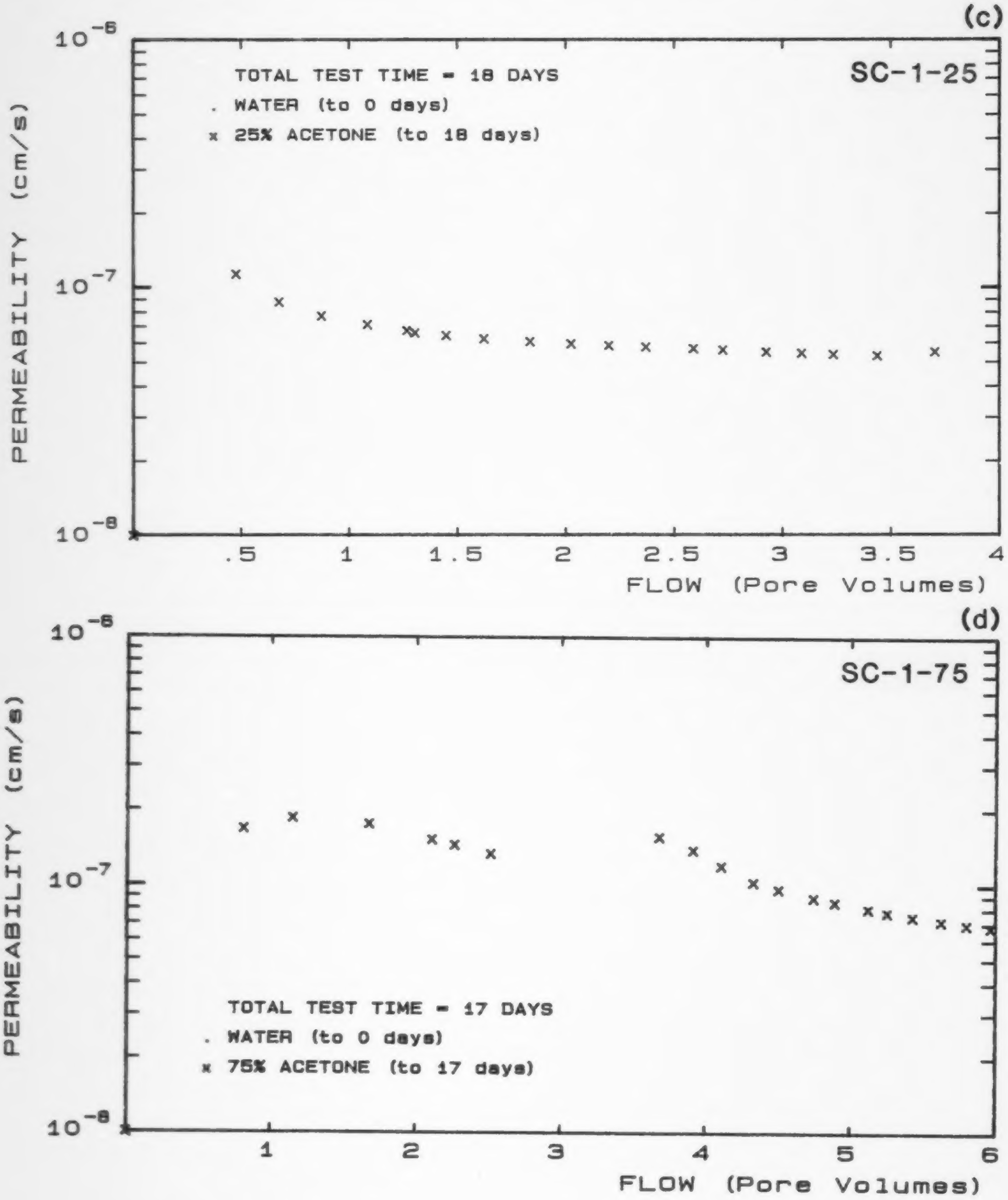


Figure C-16: Hydraulic conductivity of soil-bentonite using 1% chemically treated bentonite no. 6.



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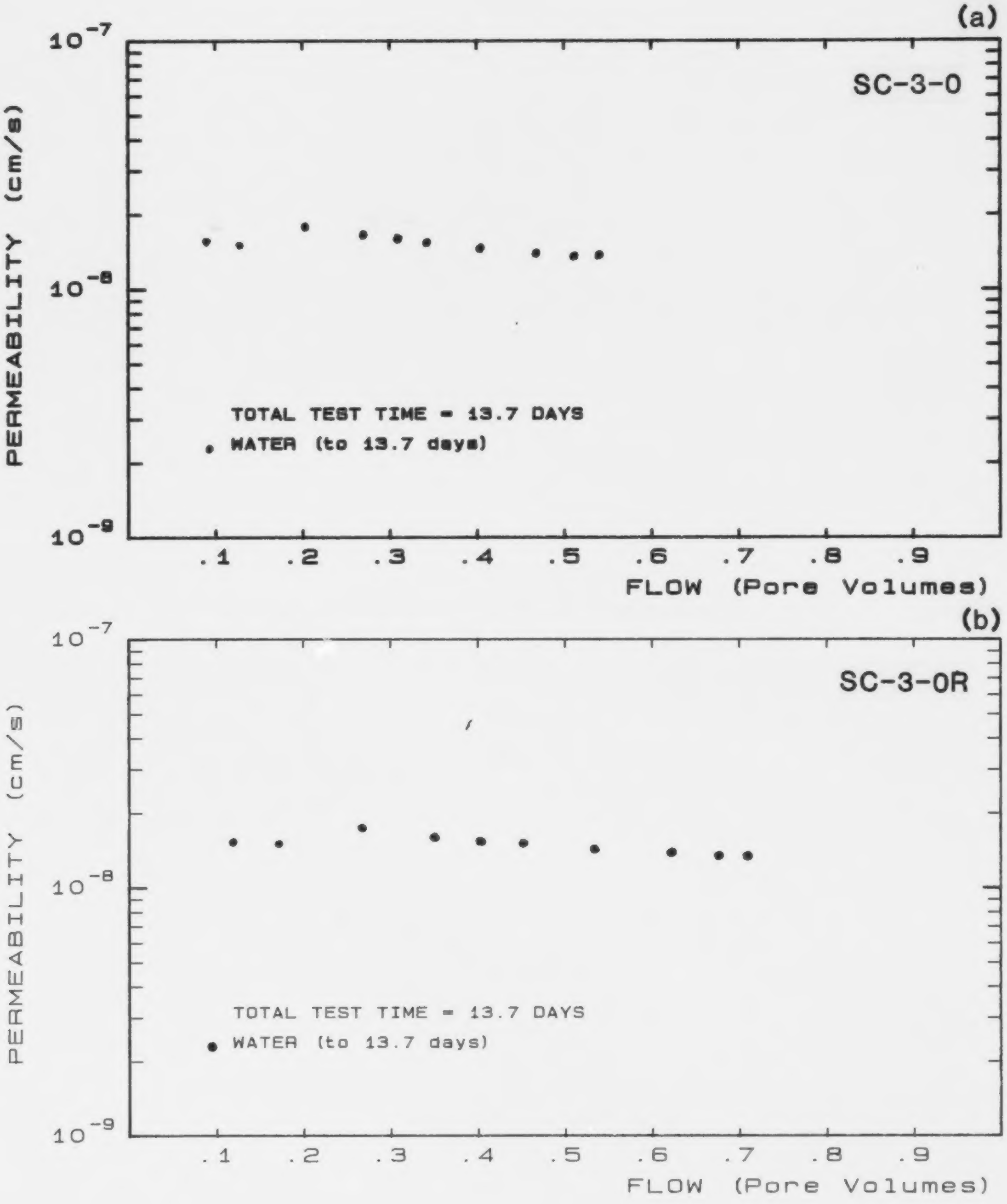
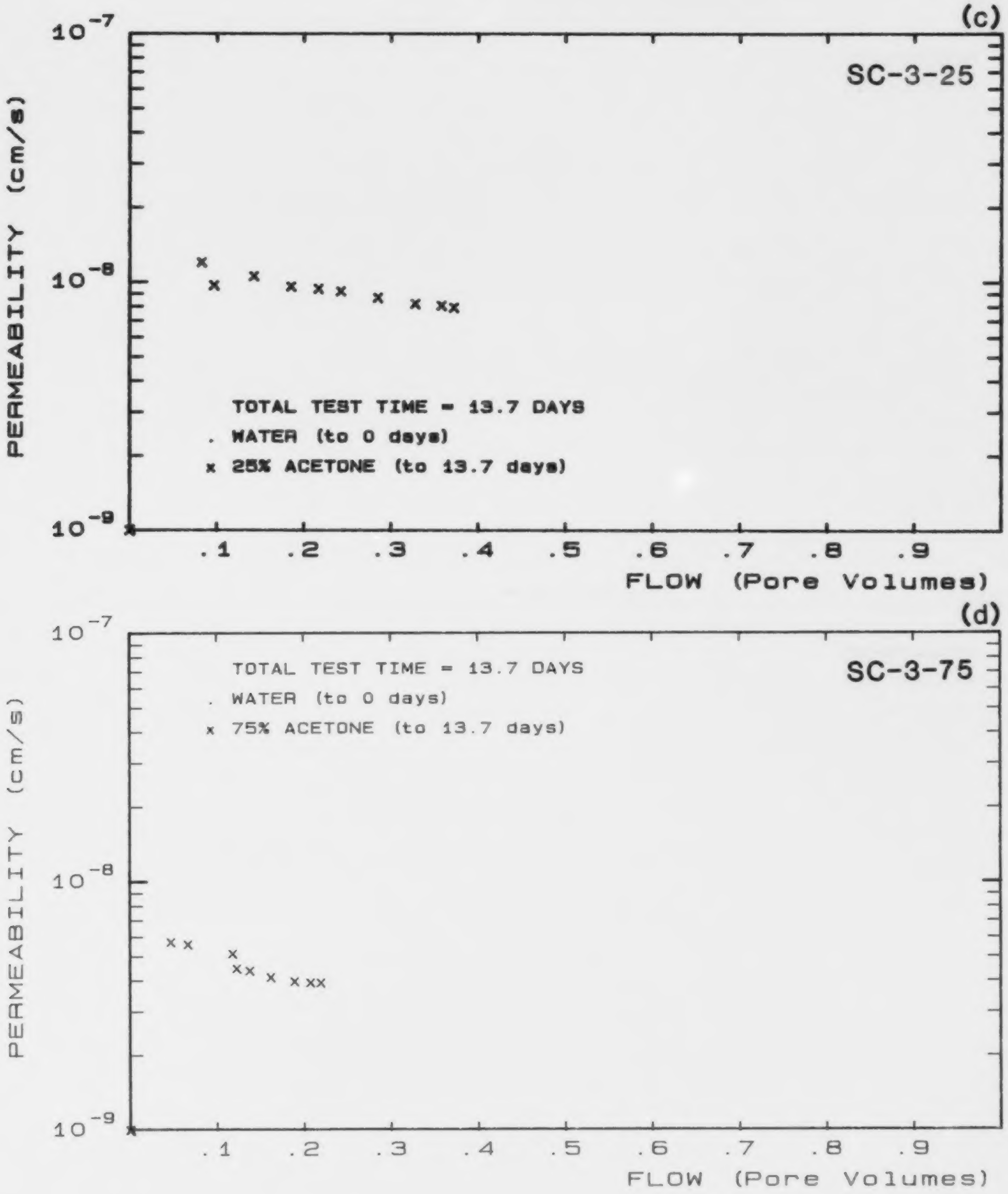


Figure C-17: Hydraulic conductivity of soil-bentonite using 3% chemically treated bentonite no. 6.



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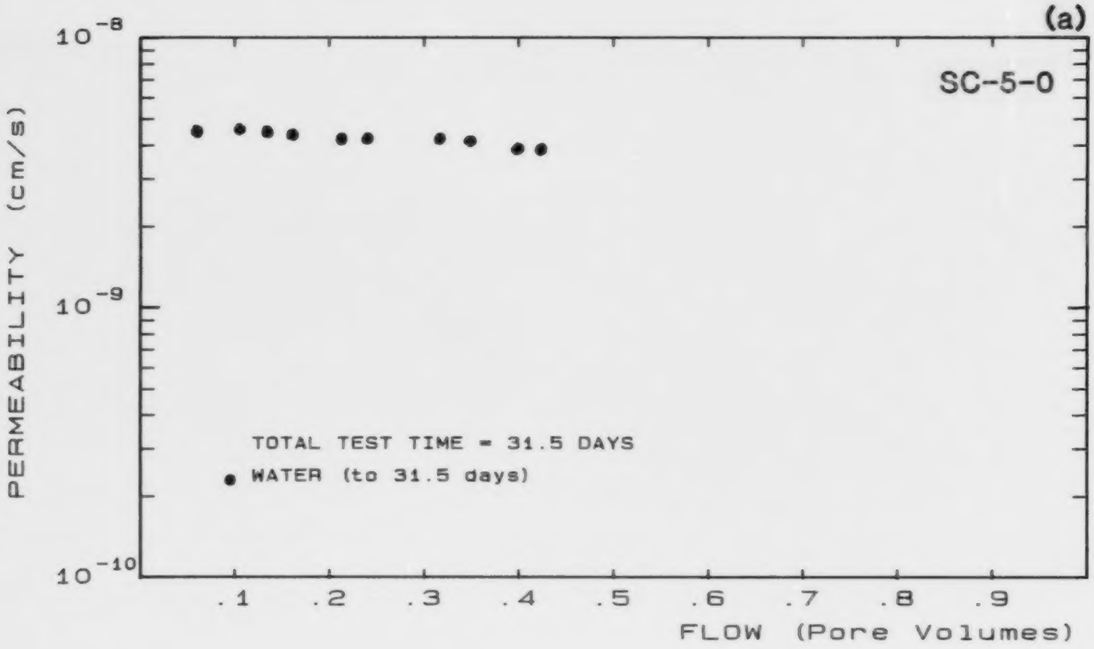
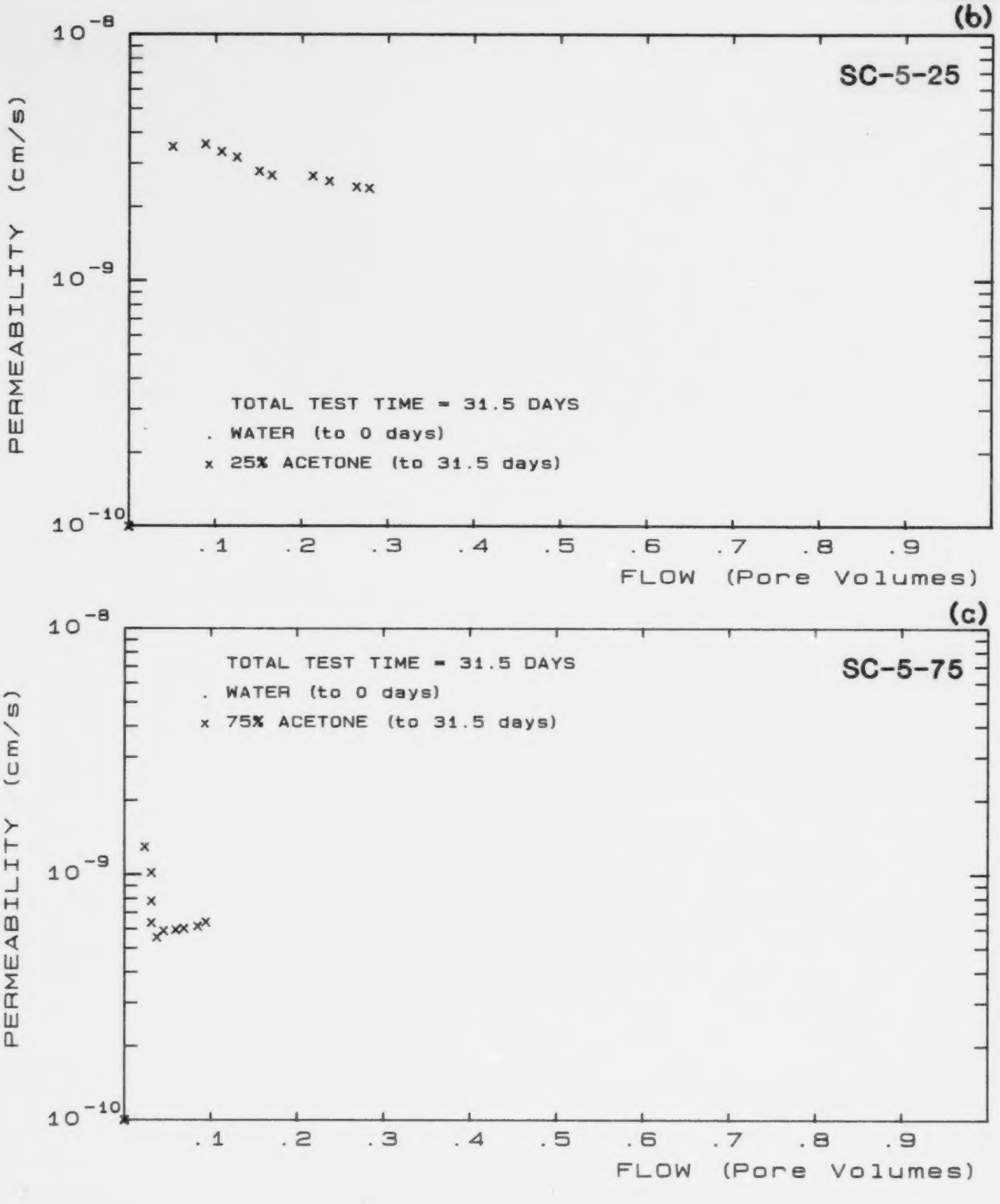


Figure C-18: Hydraulic conductivity of soil-bentonite using 5% chemically treated bentonite no. 6.



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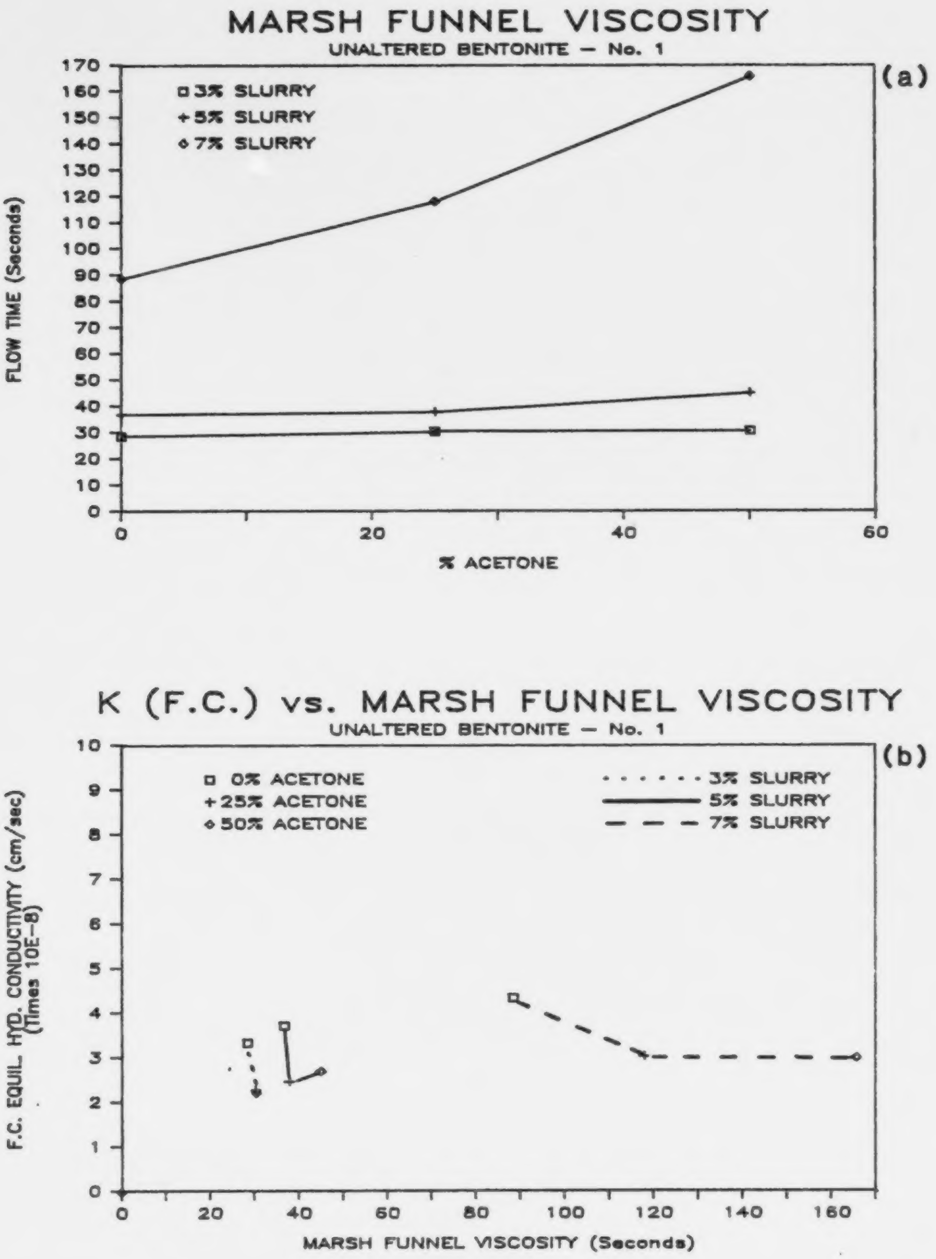


Figure C-19: (a) Phase III Marsh Funnel Viscosity test results.
(b) Correlation between indicator parameter and hydraulic conductivities of bentonite filter cakes.

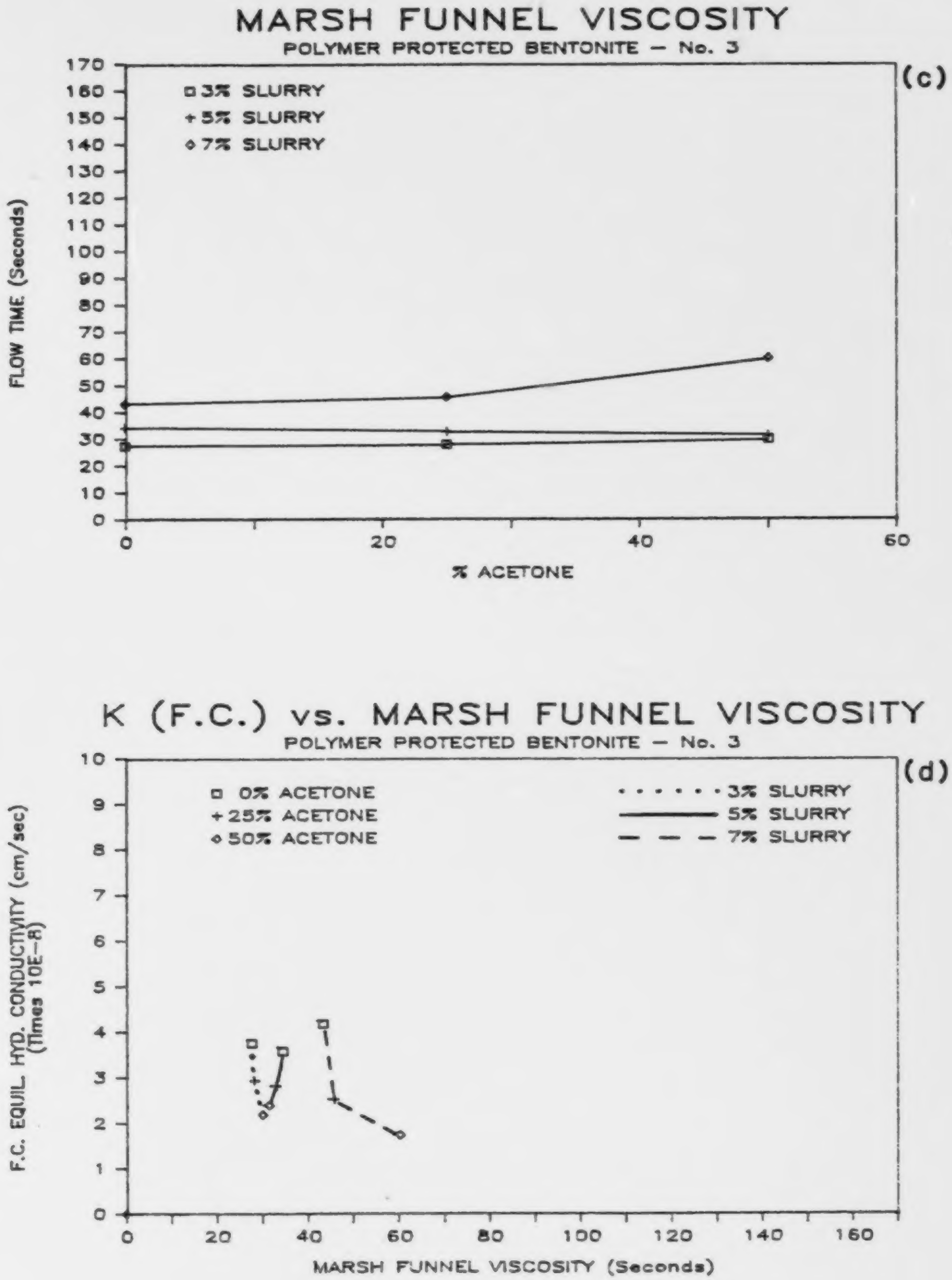
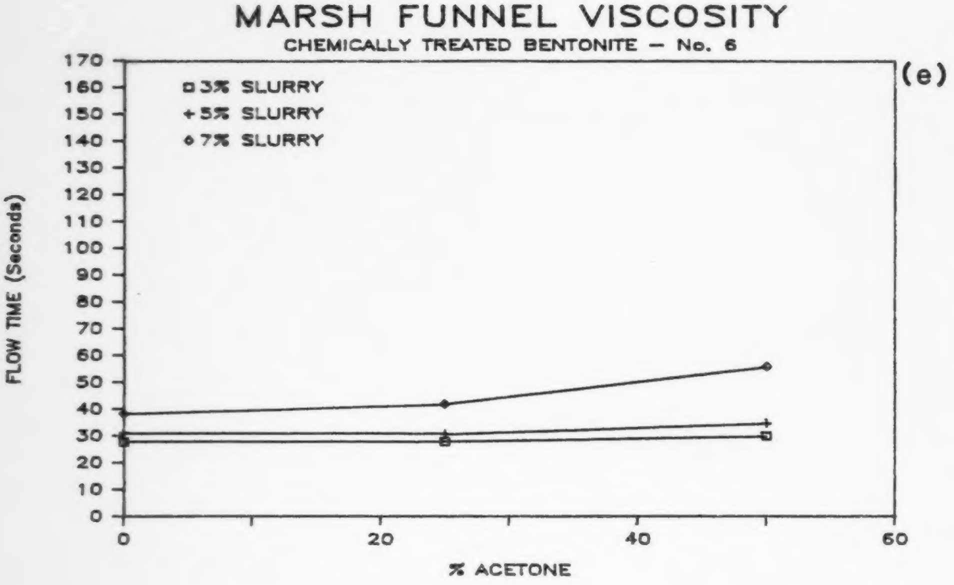


Figure C-19 contd.; (c) Phase III Marsh Funnel Viscosity test results.
(d) Correlation between indicator parameter and hydraulic conductivities of bentonite filter cakes.



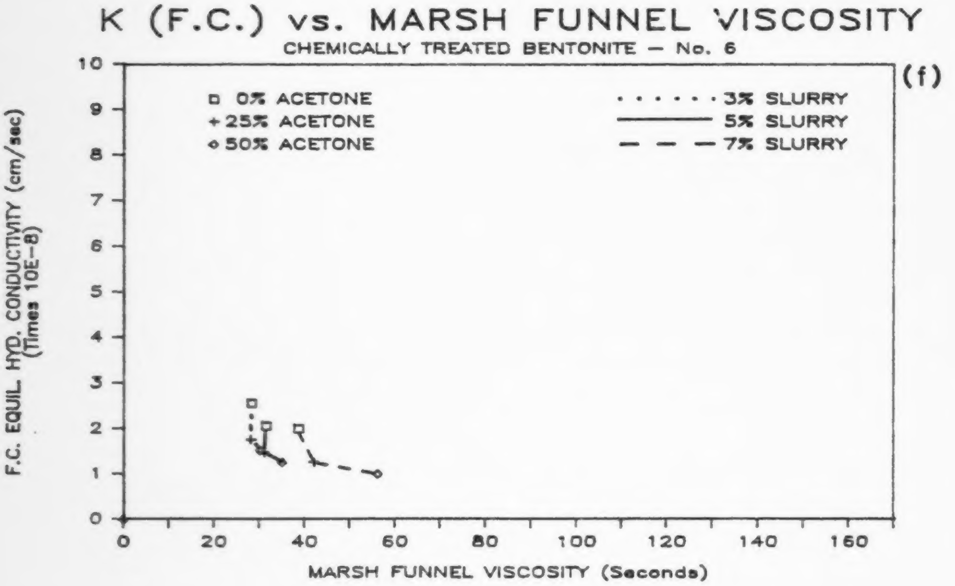


Figure C-19 contd.; (e) Phase III Marsh Funnel Viscosity test results.
(f) Correlation between indicator parameter and hydraulic conductivities of bentonite filter cakes.

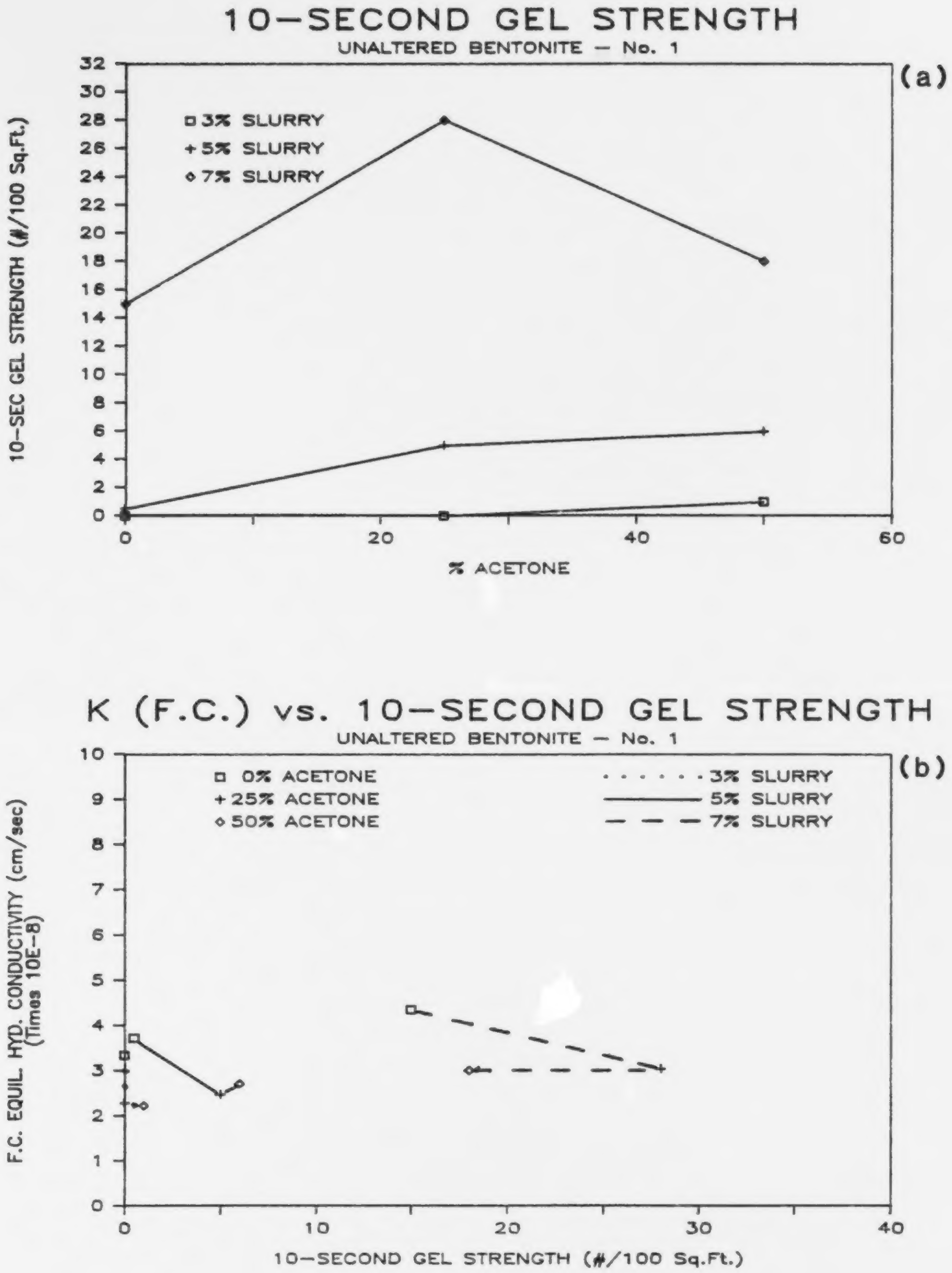
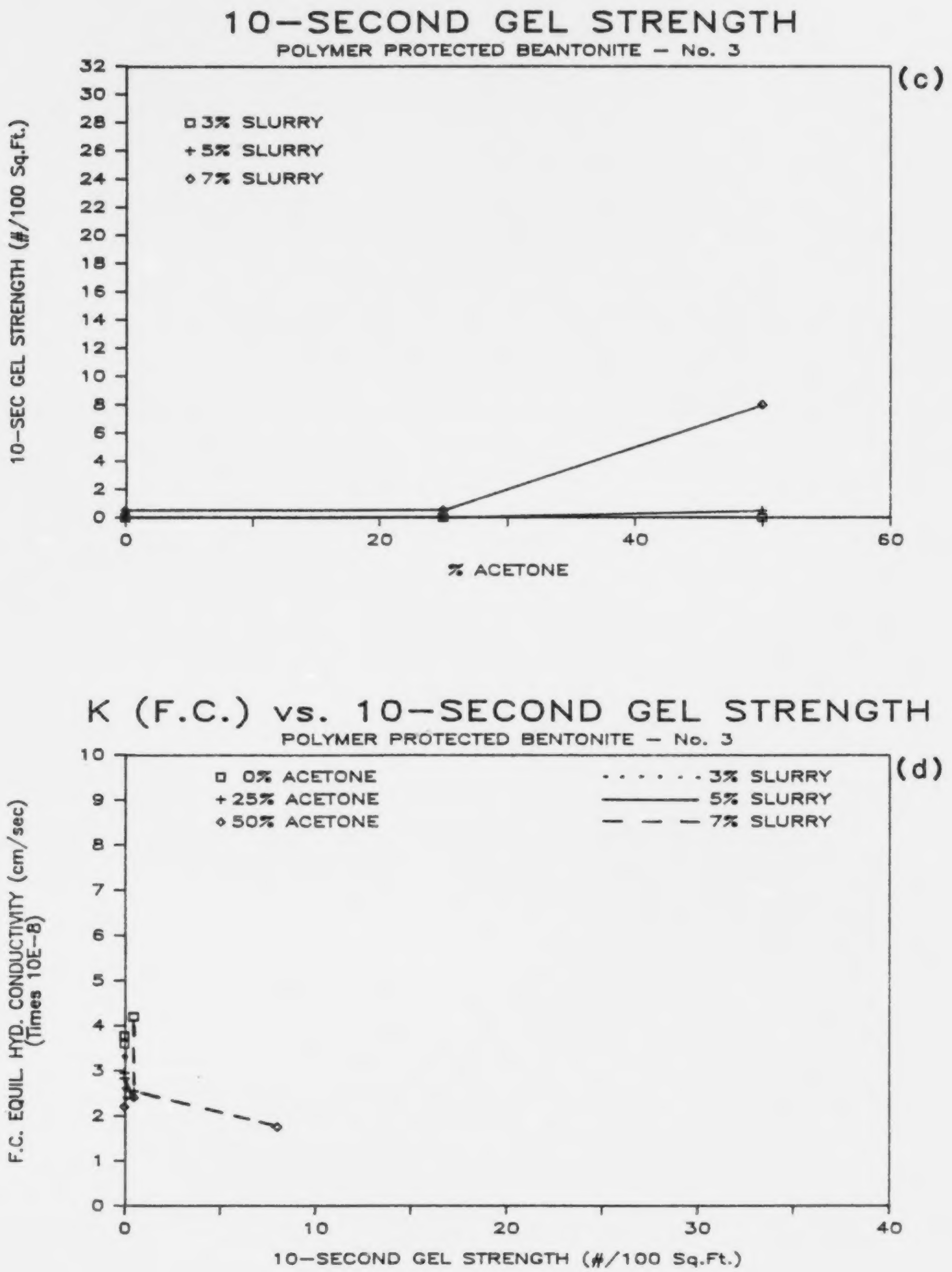


Figure C-20: (a) Phase III 10-Second Gel Strength test results.
(b) Correlation between indicator parameter and hydraulic conductivities of bentonite filter cakes.



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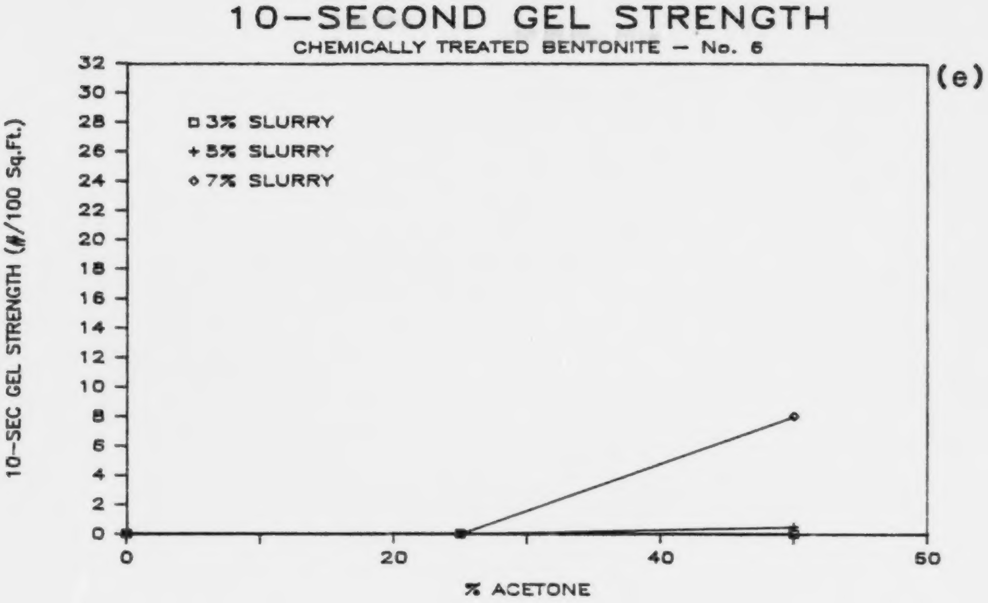
(d) Correlation between indicator parameter and hydraulic conductivities of bentonite filter cakes.



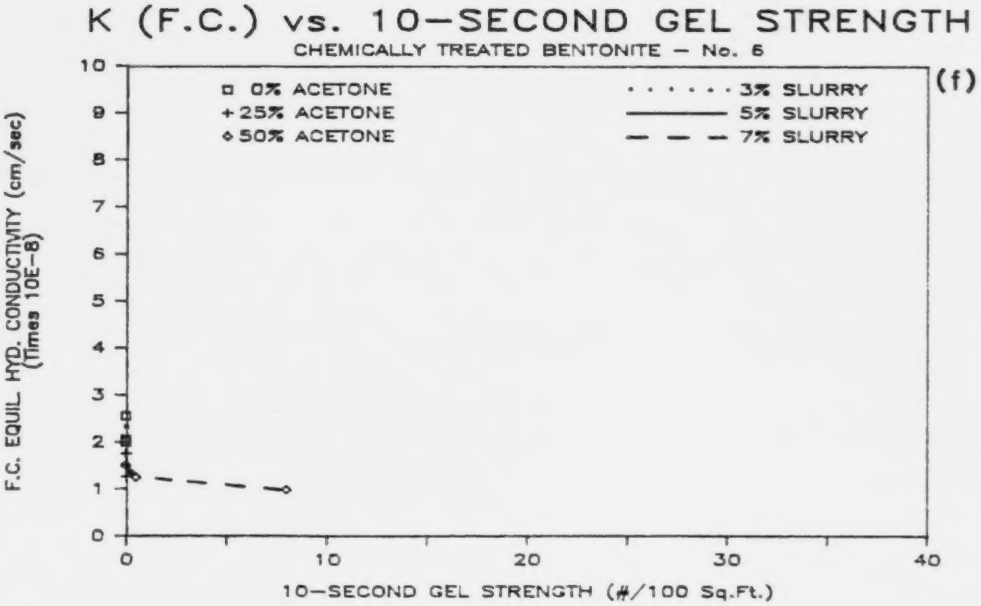


Figure C-20 contd.; (e) Phase III 10-Second Gel Strength test results. (f) Correlation between indicator parameter and hydraulic conductivities of bentonite filter cakes.

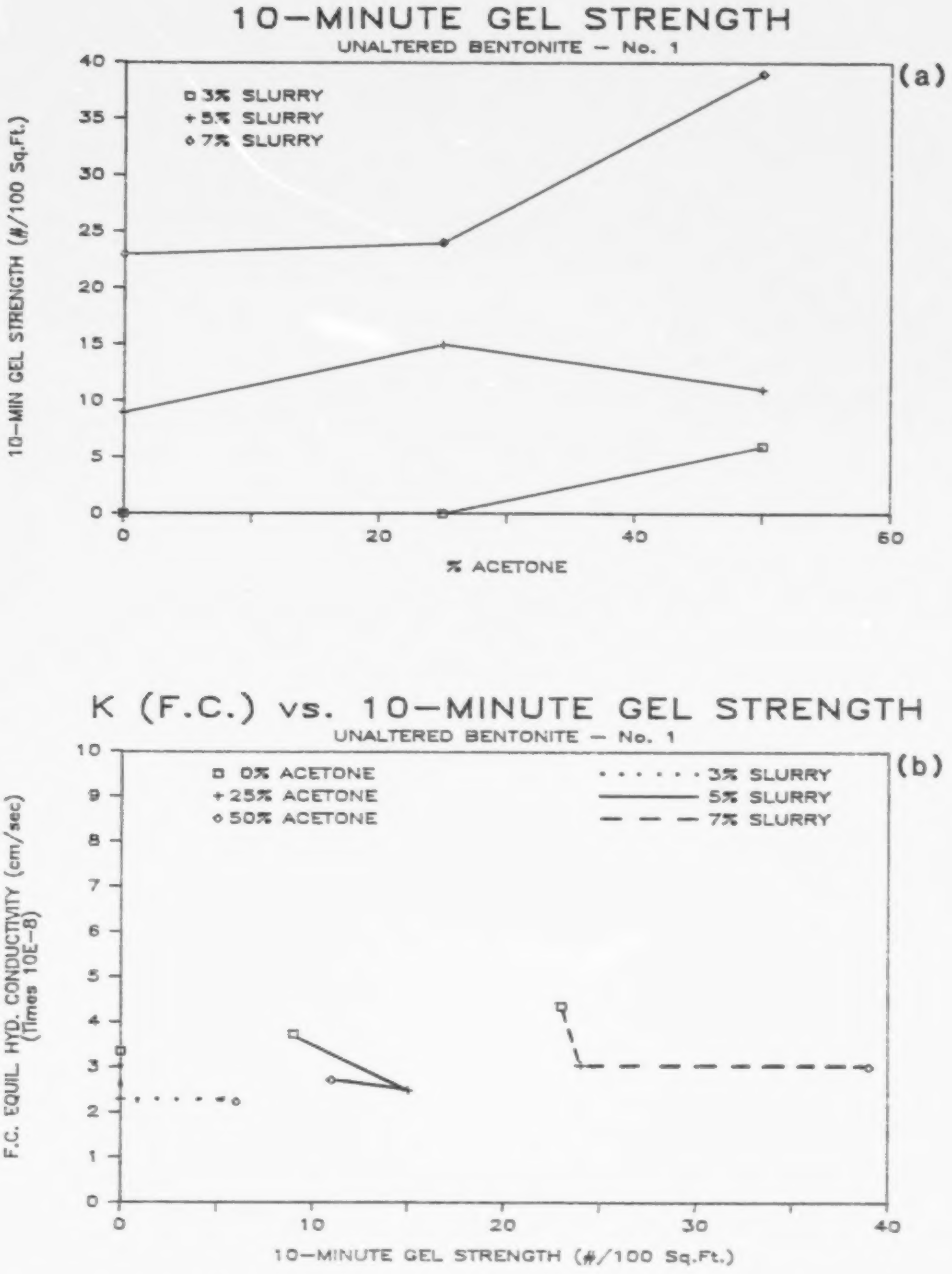
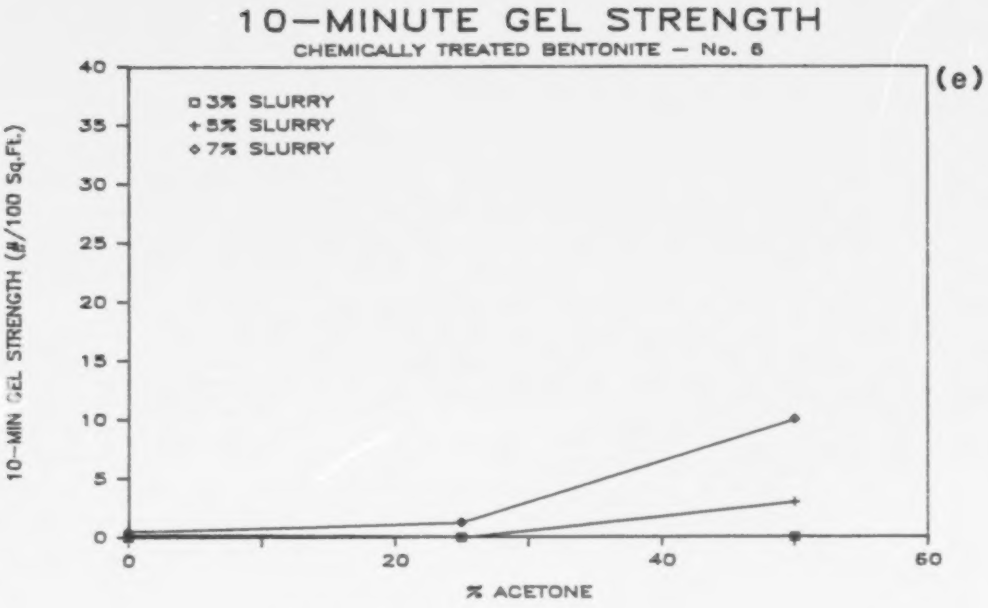


Figure C-21: (a) Phase III 10-Minute Gel Strength test results.
(b) Correlation between indicator parameter and hydraulic conductivities of bentonite filter cakes.



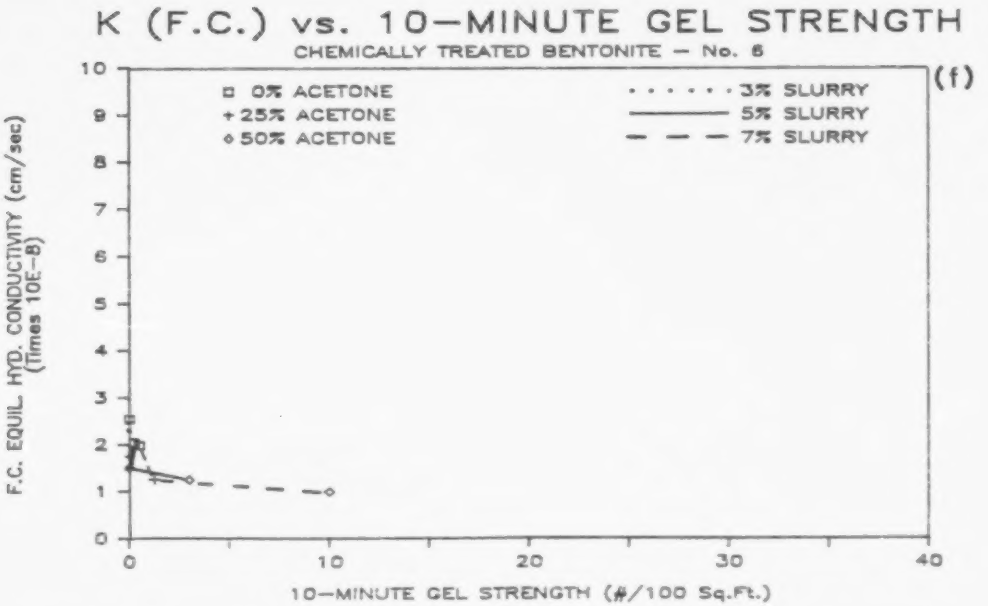
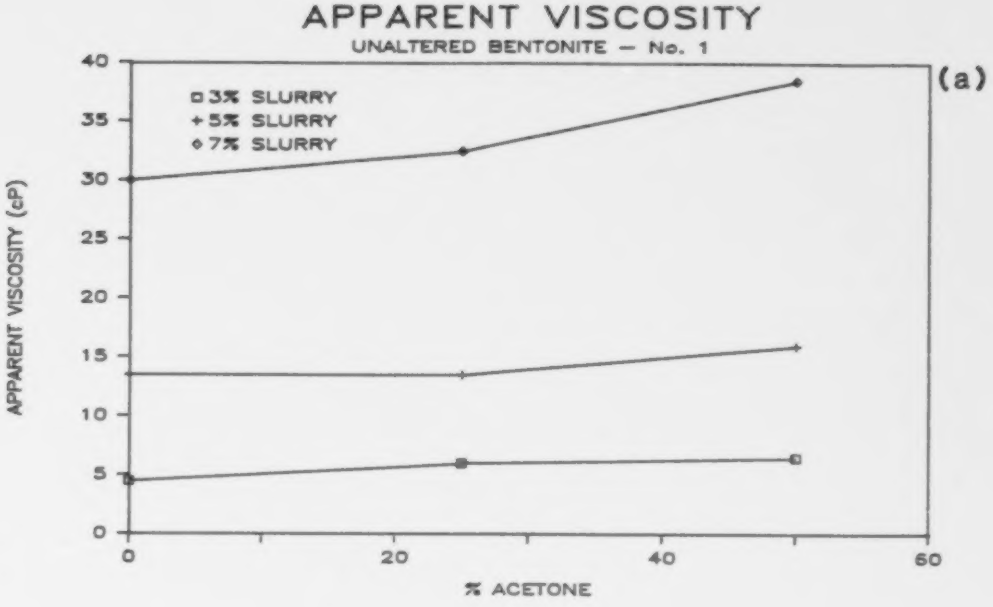


Figure C-21 contd.; (e) Phase III 10-Minute Gel Strength test results.
(f) Correlation between indicator parameter and hydraulic conductivities of bentonite filter cakes.



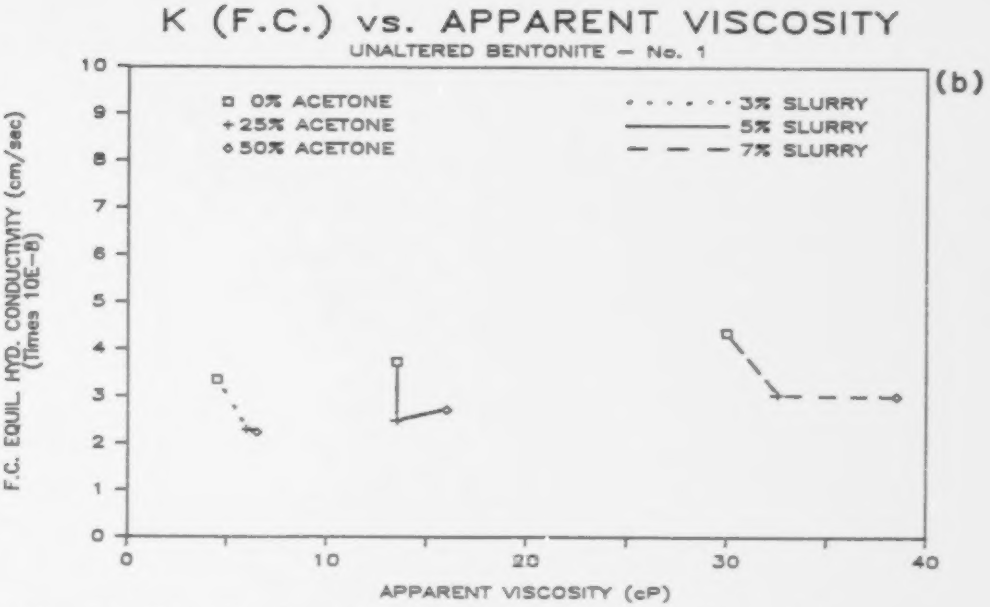
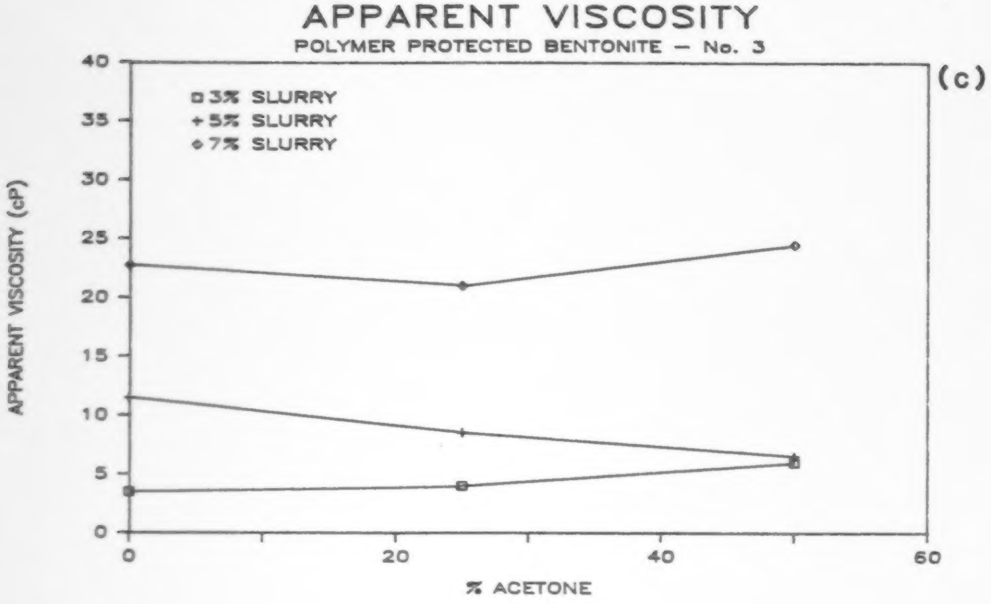


Figure C-22: (a) Phase III Apparent Viscosity test results.
(b) Correlation between indicator parameter and hydraulic conductivities of bentonite filter cakes.



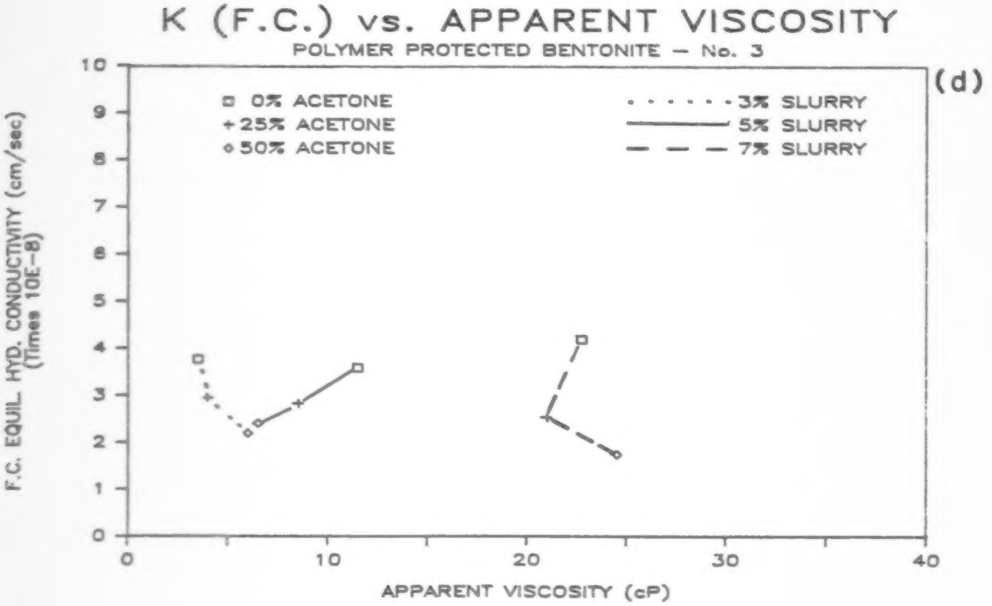
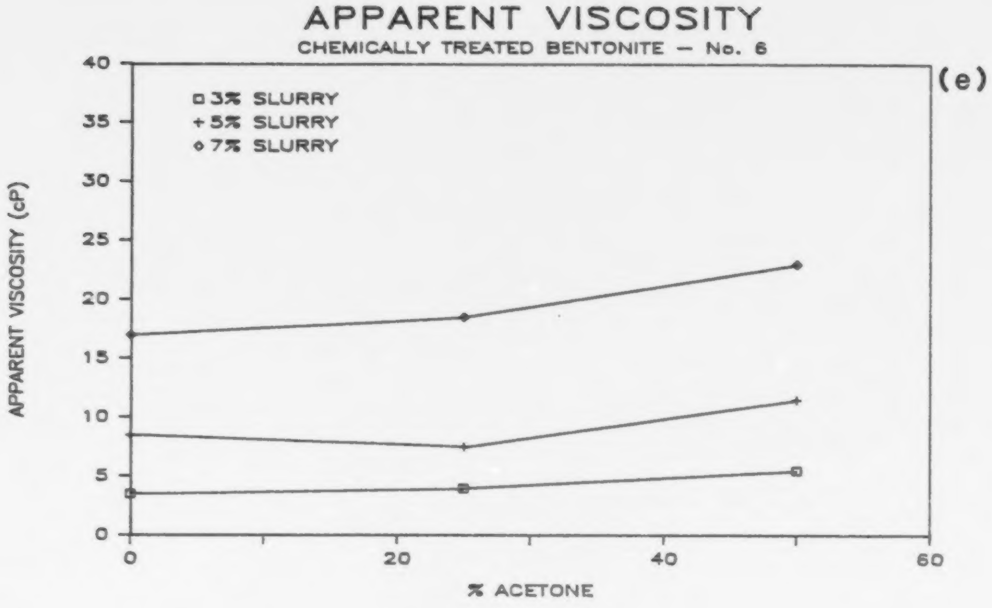


Figure C-22 contd.; (c) Phase III Apparent Viscosity test results.
(d) Correlation between indicator parameter and hydraulic conductivities of bentonite filter cakes.



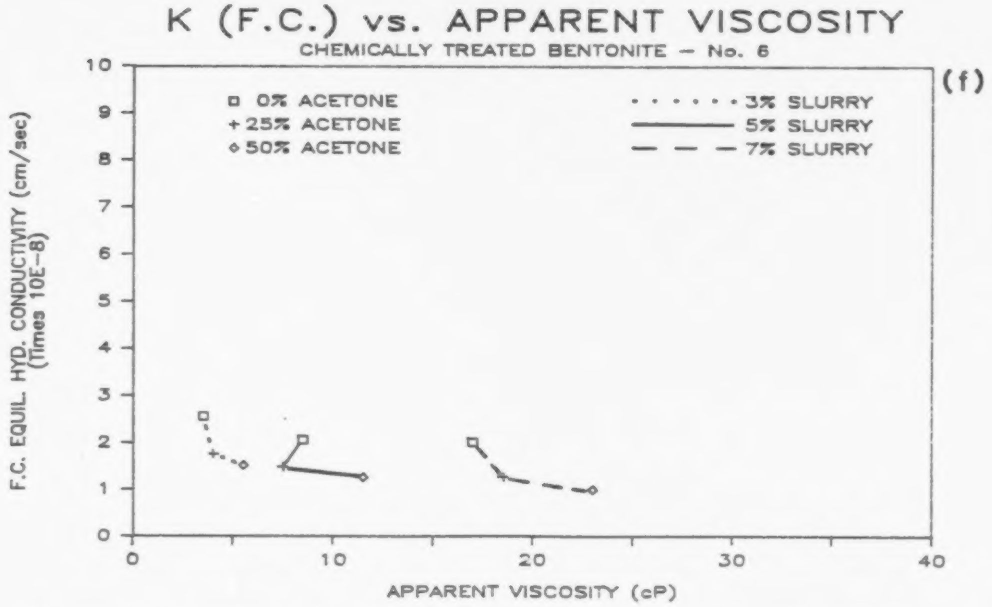


Figure C-22 contd.; (e) Phase III Apparent Viscosity test results.
(f) Correlation between indicator parameter and hydraulic conductivities of bentonite filter cakes.

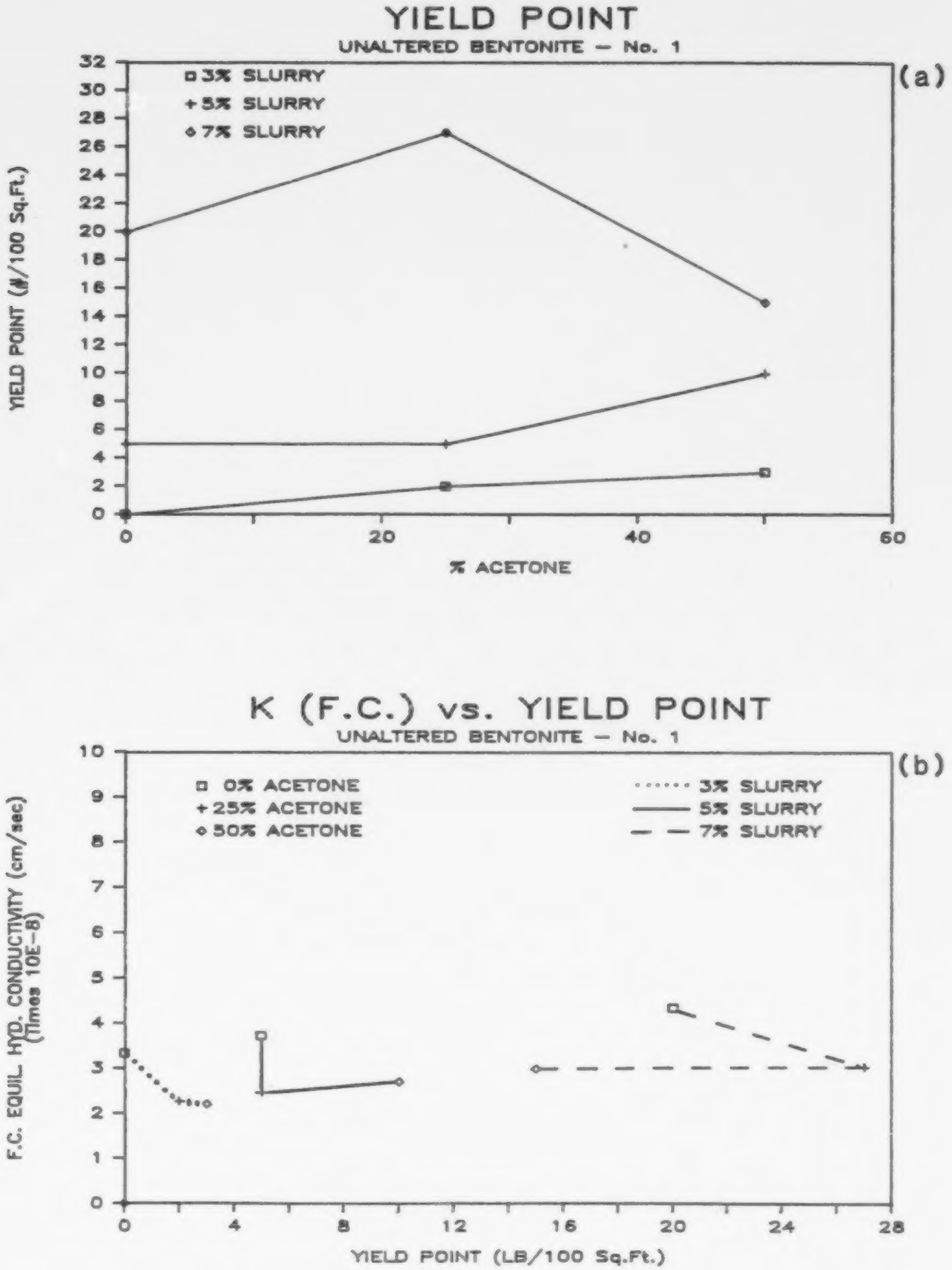
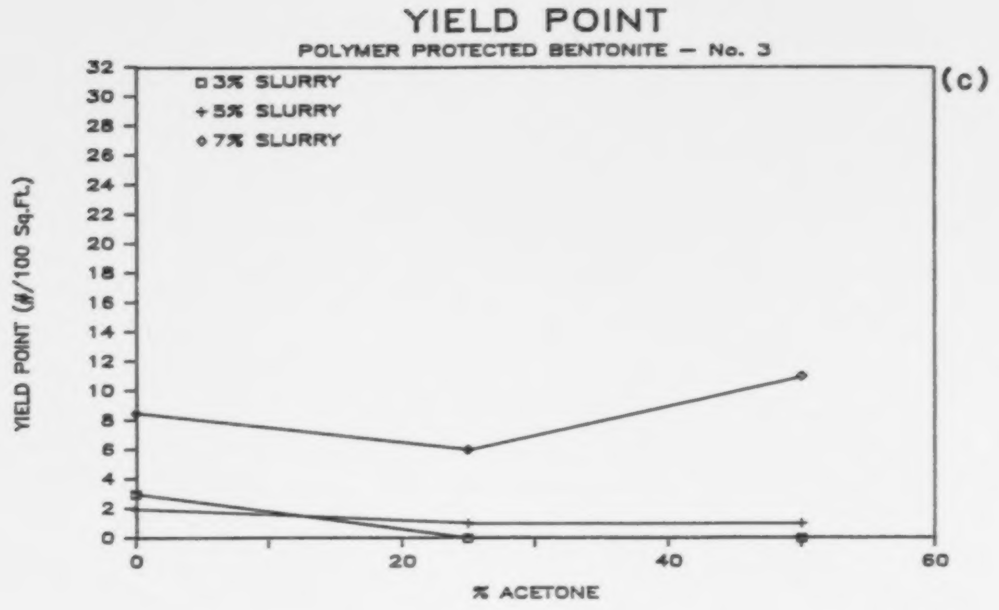


Figure C-23: (a) Phase III Yield Point test results.
(b) Correlation between indicator parameter and hydraulic conductivities of bentonite filter cakes.



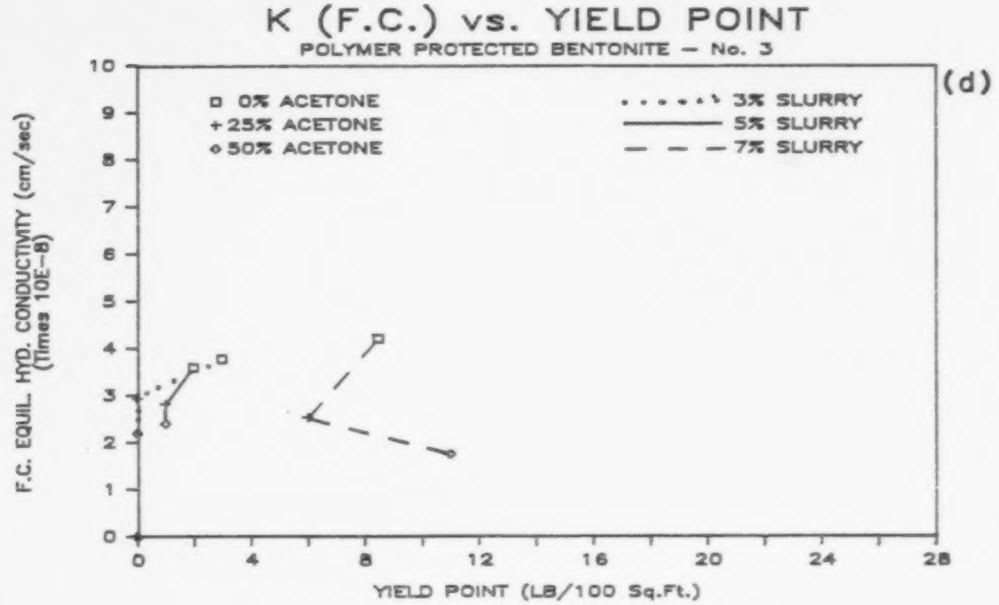


Figure C-23 contd.; (c) Phase III Yield Point test results.
(d) Correlation between indicator parameter and hydraulic conductivities of bentonite filter cakes.

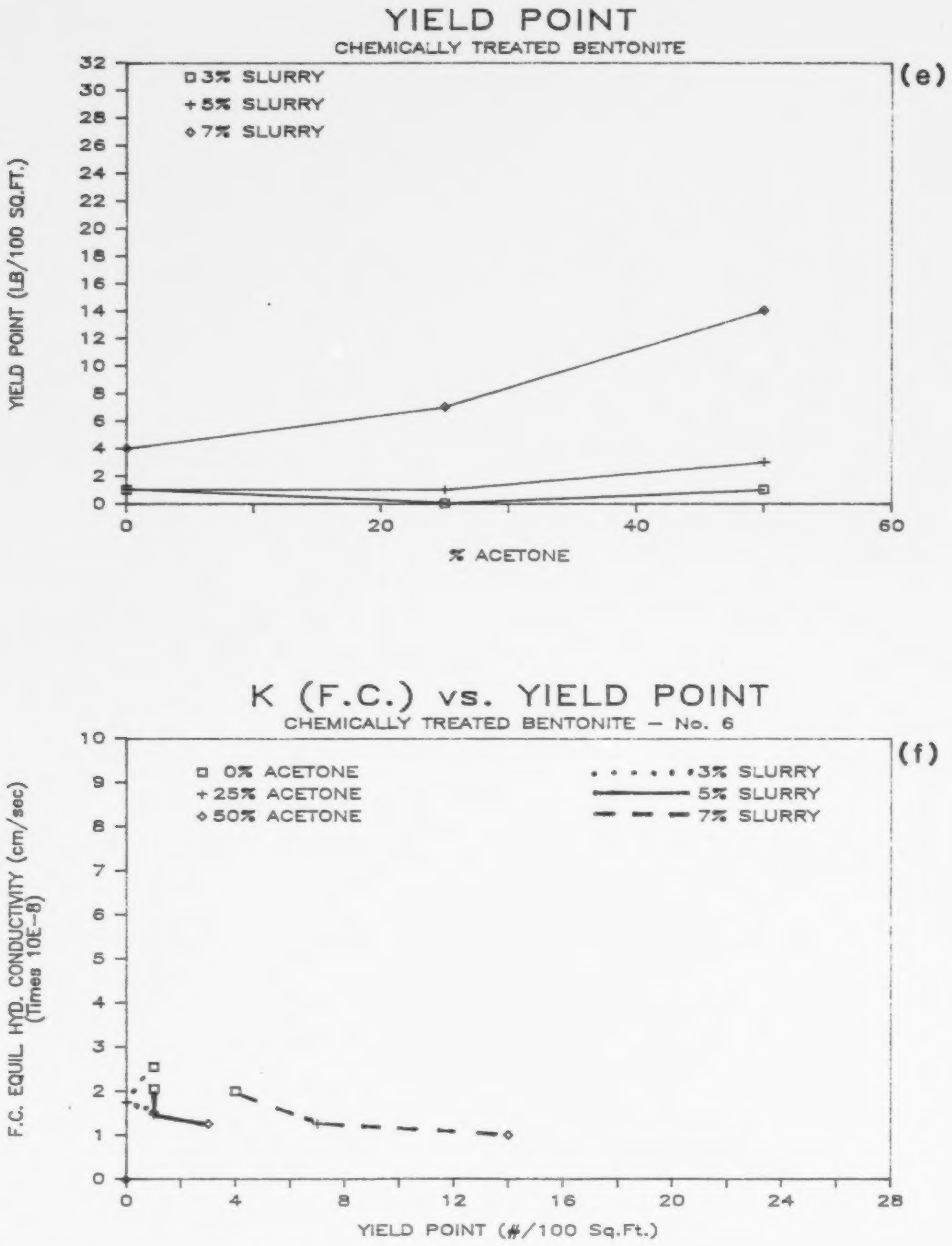
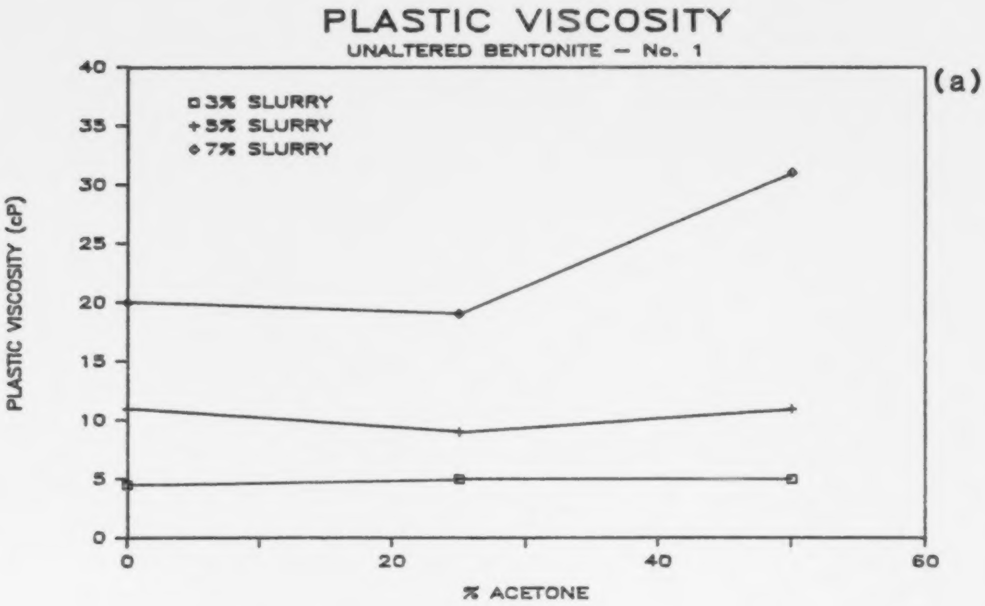


Figure C-23 contd.; (e) Phase III Yield Point test results.
(f) Correlation between indicator parameter and hydraulic conductivities of bentonite filter cakes.



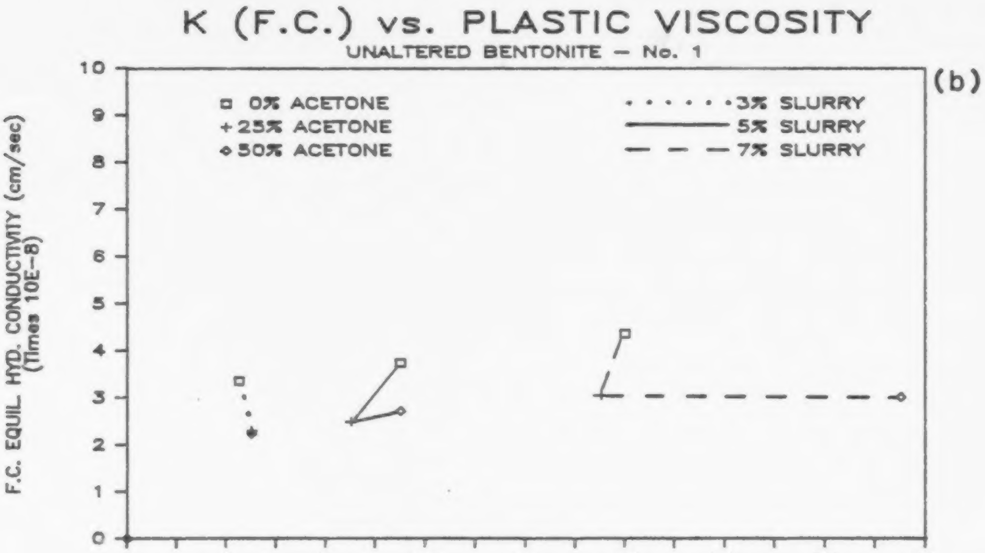
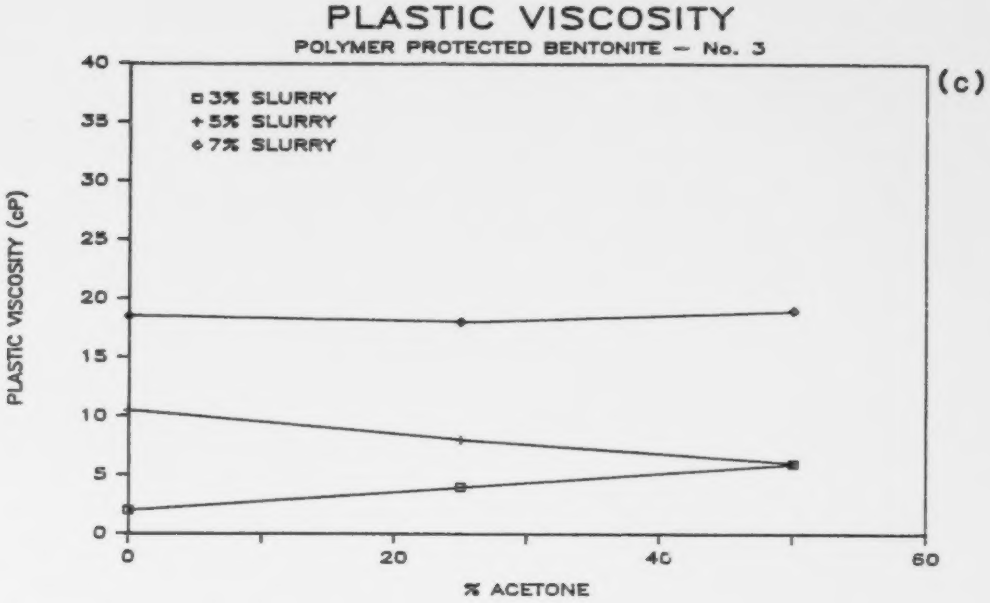


Figure C-24: (a) Phase III Plastic Viscosity test results.
(b) Correlation between indicator parameter and hydraulic conductivities of bentonite filter cakes.



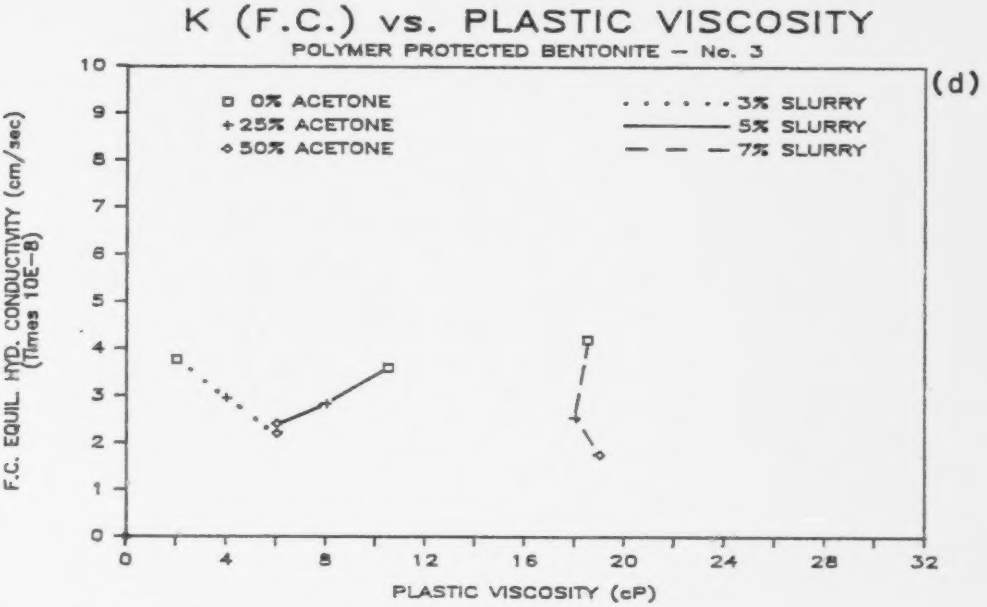
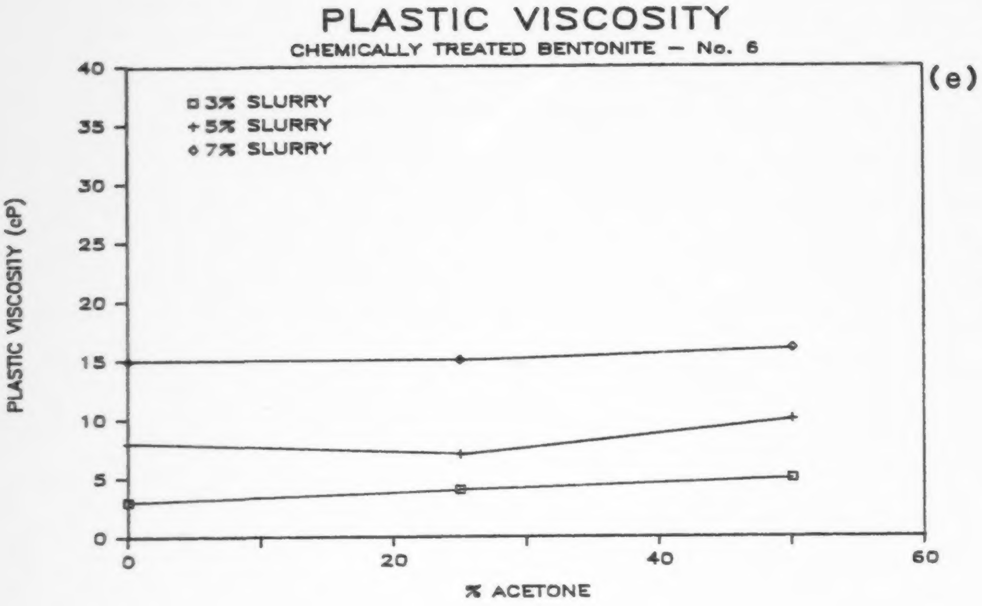


Figure C-24 contd.; (c) Phase III Plastic Viscosity test results.
(d) Correlation between indicator parameter and hydraulic conductivities of bentonite filter cakes.



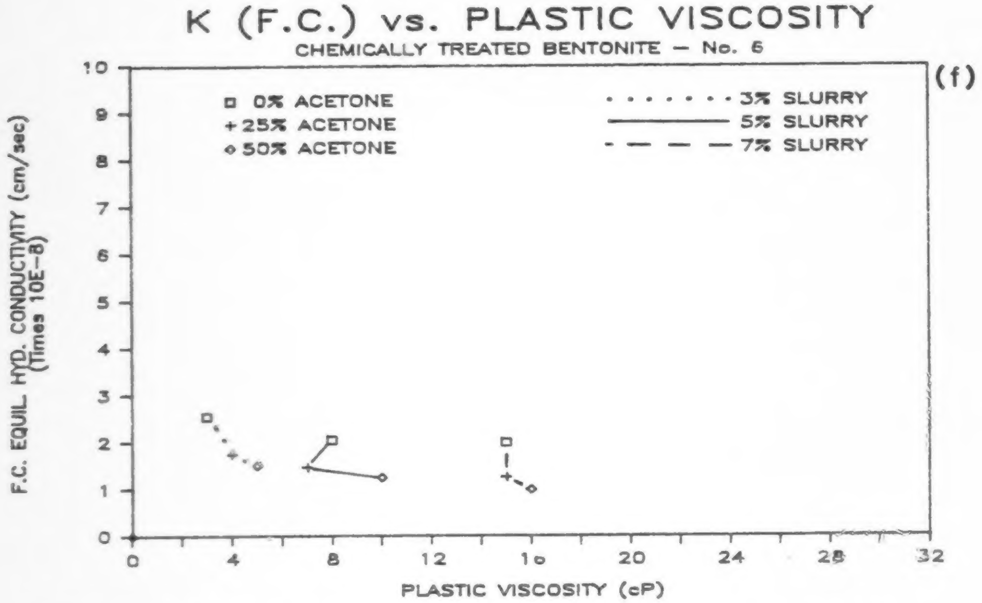


Figure C-24 contd.; (e) Phase III Plastic Viscosity test results.
(f) Correlation between indicator parameter and hydraulic conductivities of bentonite filter cakes.

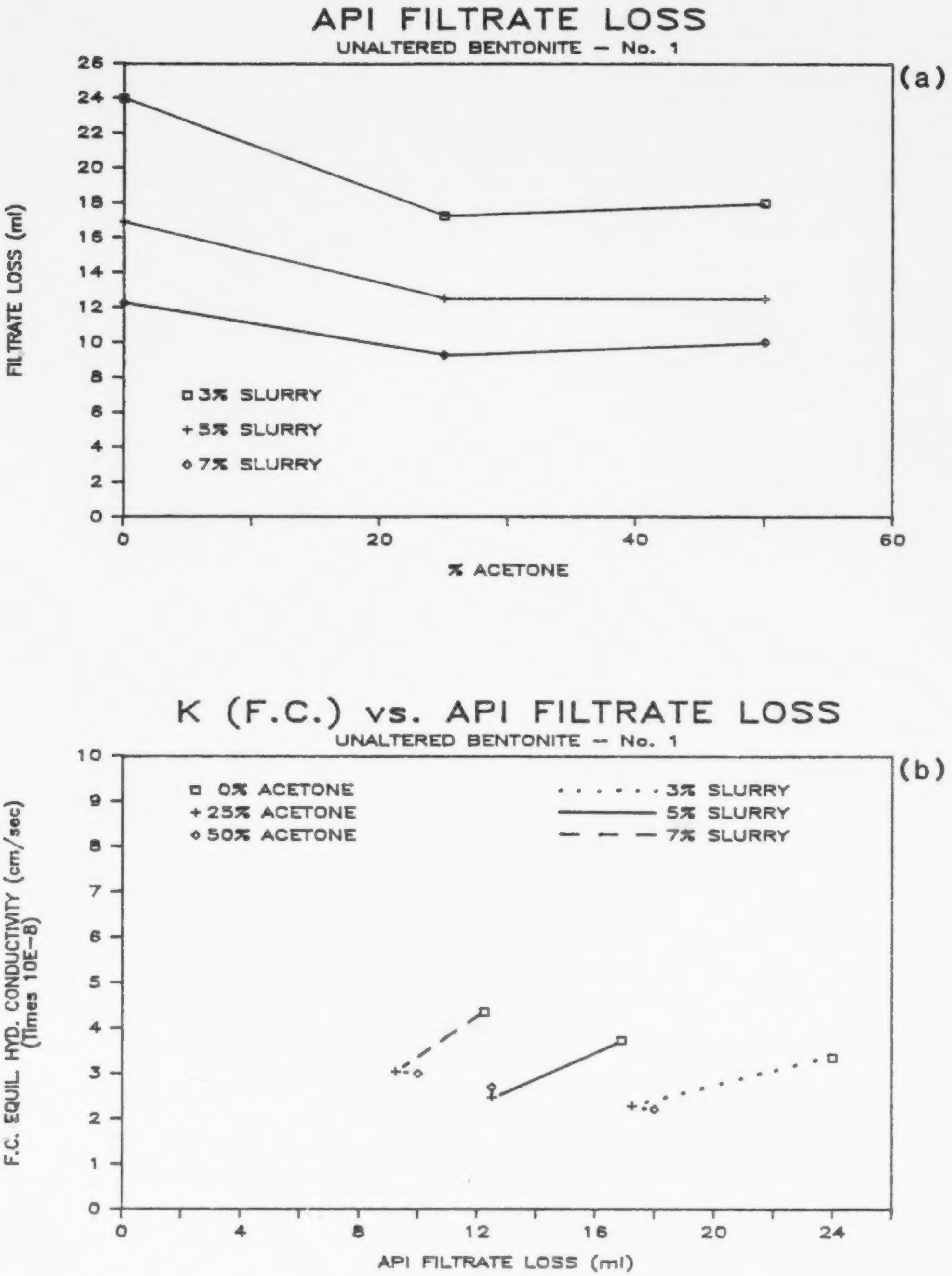
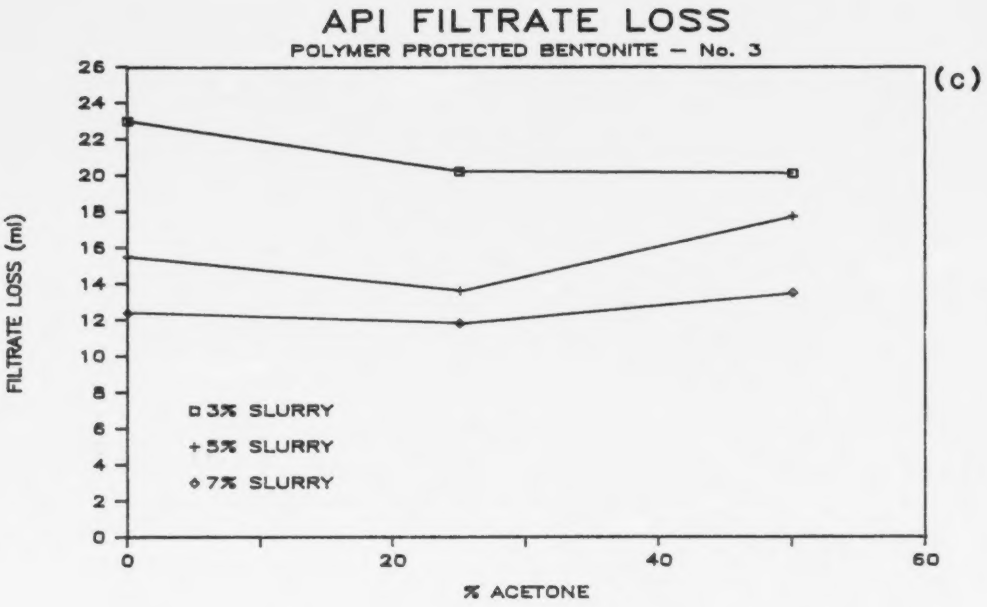


Figure C-25: (a) Phase III API Filtrate Loss test results.
(b) Correlation between indicator parameter and hydraulic conductivities of bentonite filter cakes.



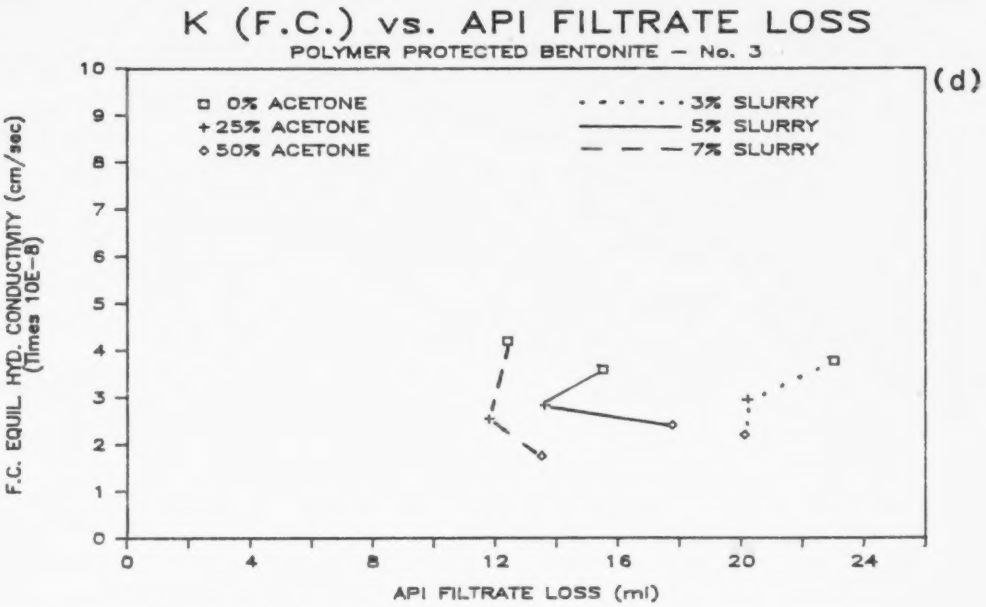
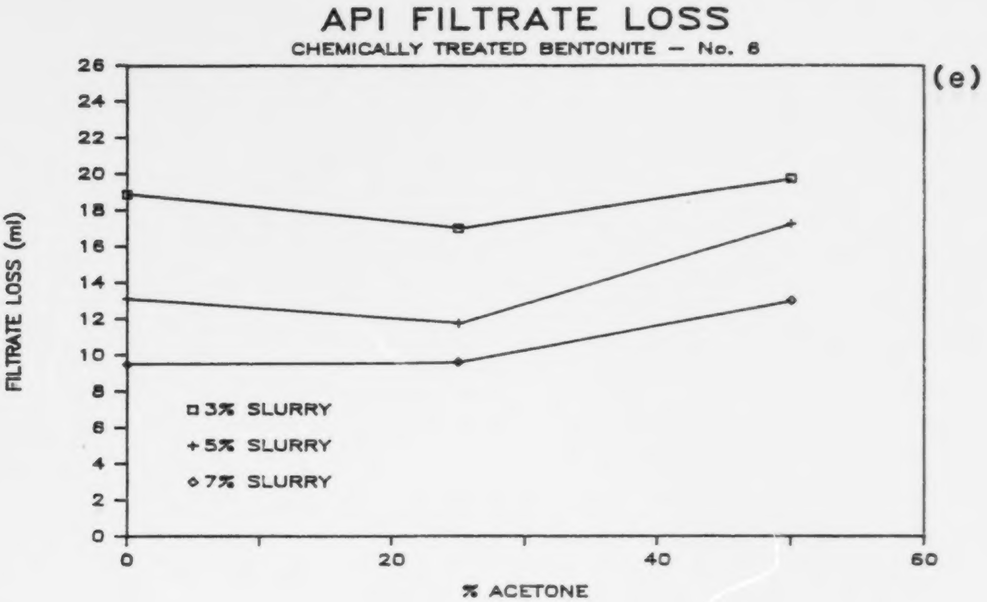


Figure C-25 contd.; (c) Phase III API Filtrate Loss test results.
(d) Correlation between indicator parameter and hydraulic conductivities of bentonite filter cakes.



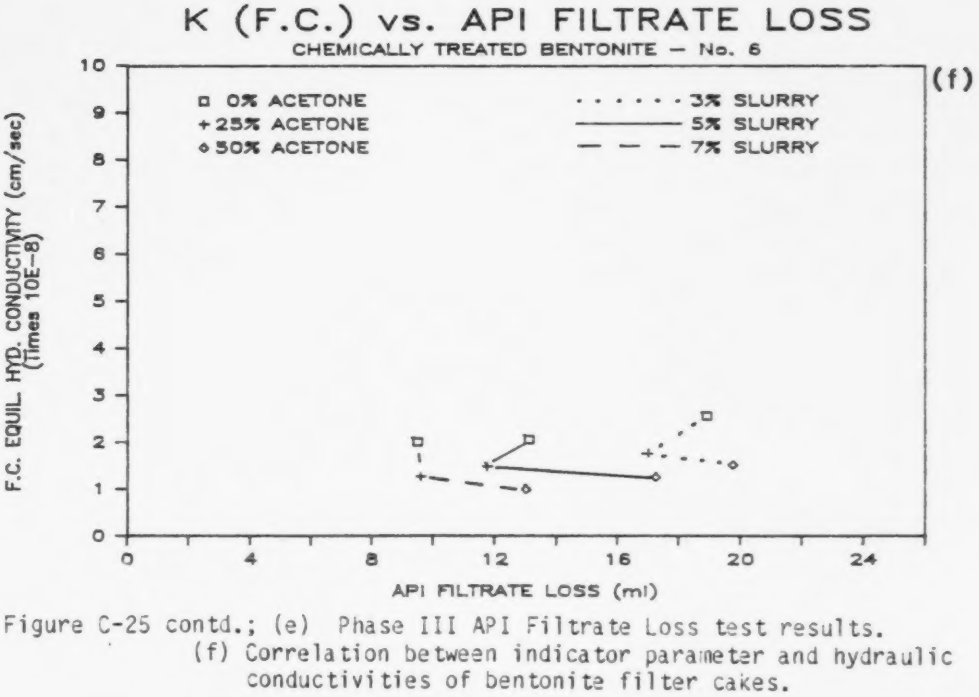


Figure C-25 contd.; (e) Phase III API Filtrate Loss test results.
(f) Correlation between indicator parameter and hydraulic conductivities of bentonite filter cakes.

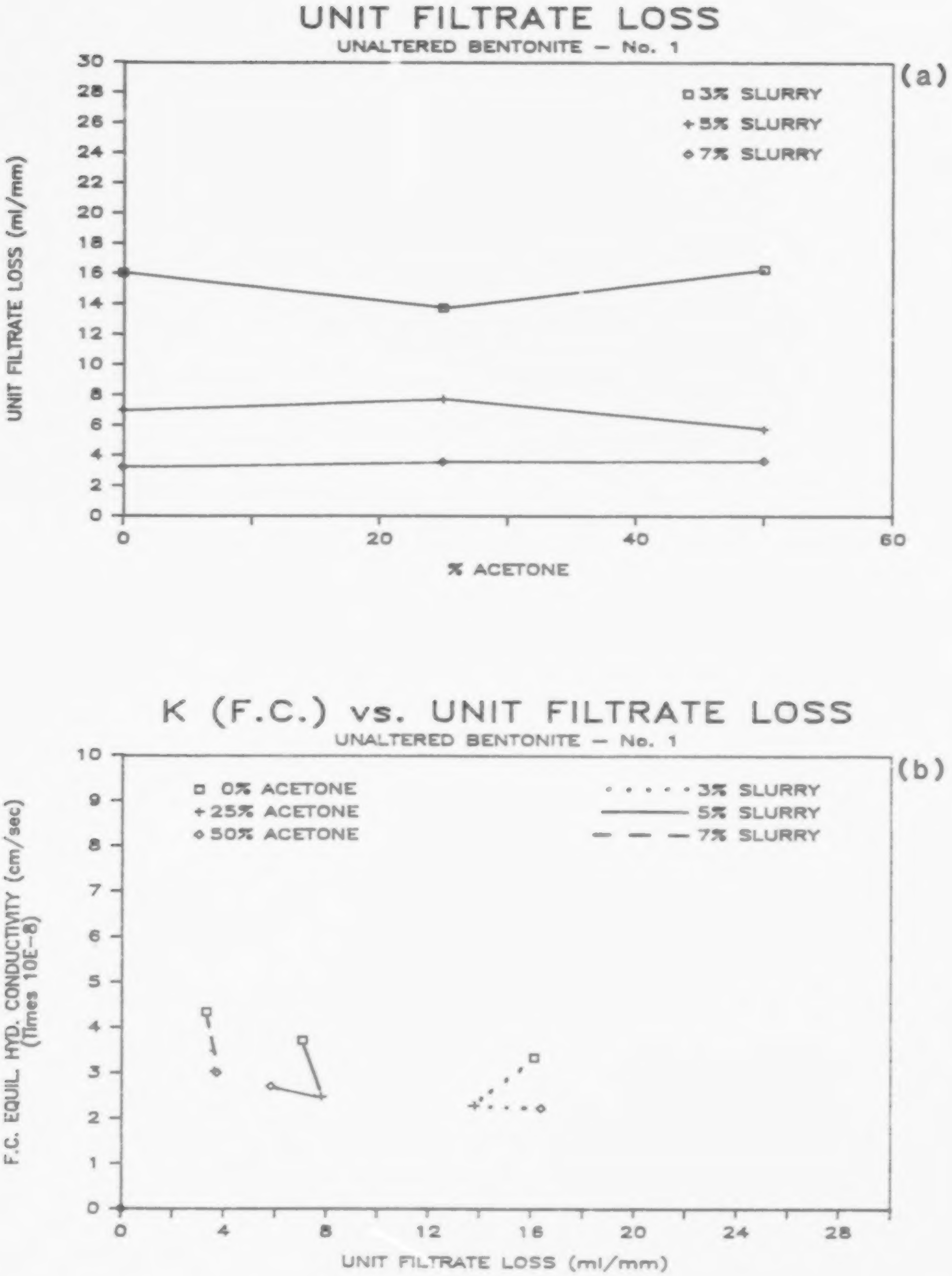
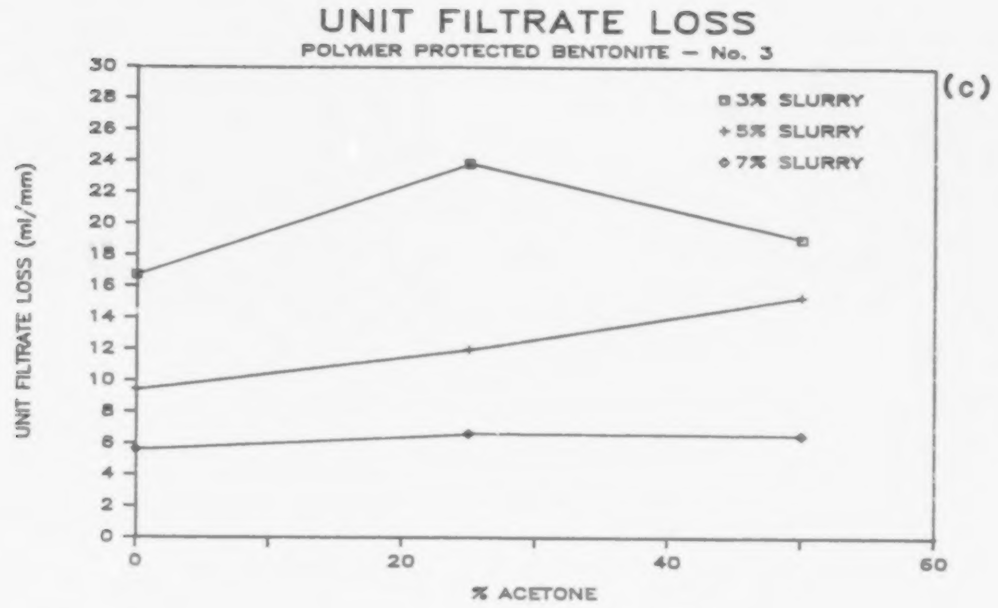


Figure C-26: (a) Phase III Unit Filtrate Loss test results.
(b) Correlation between indicator parameter and hydraulic conductivities of bentonite filter cakes.



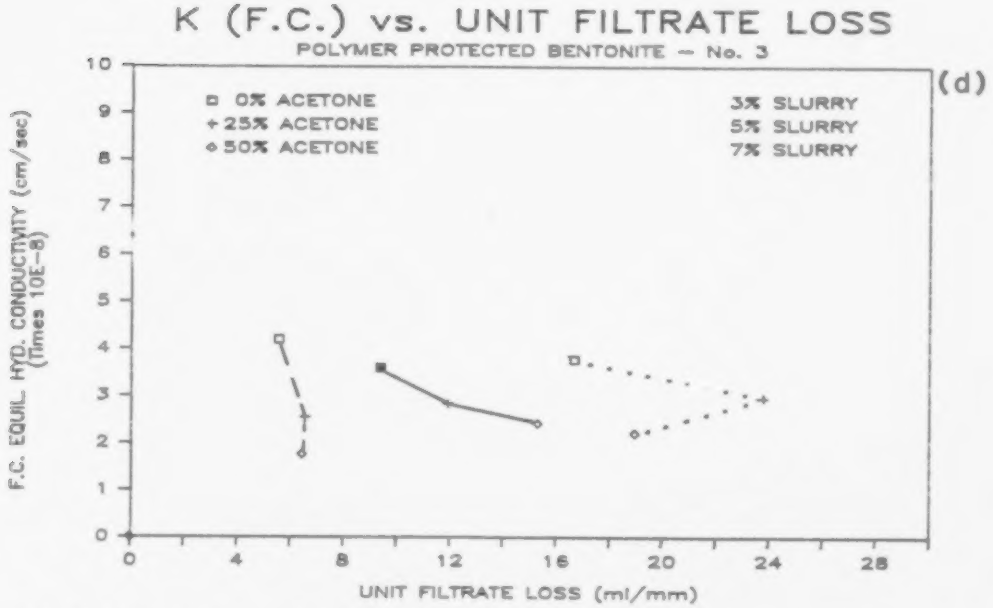


Figure C-26 contd.; (c) Phase III Unit Filtrate Loss test results.
(d) Correlation between indicator parameter and hydraulic conductivities of bentonite filter cakes.

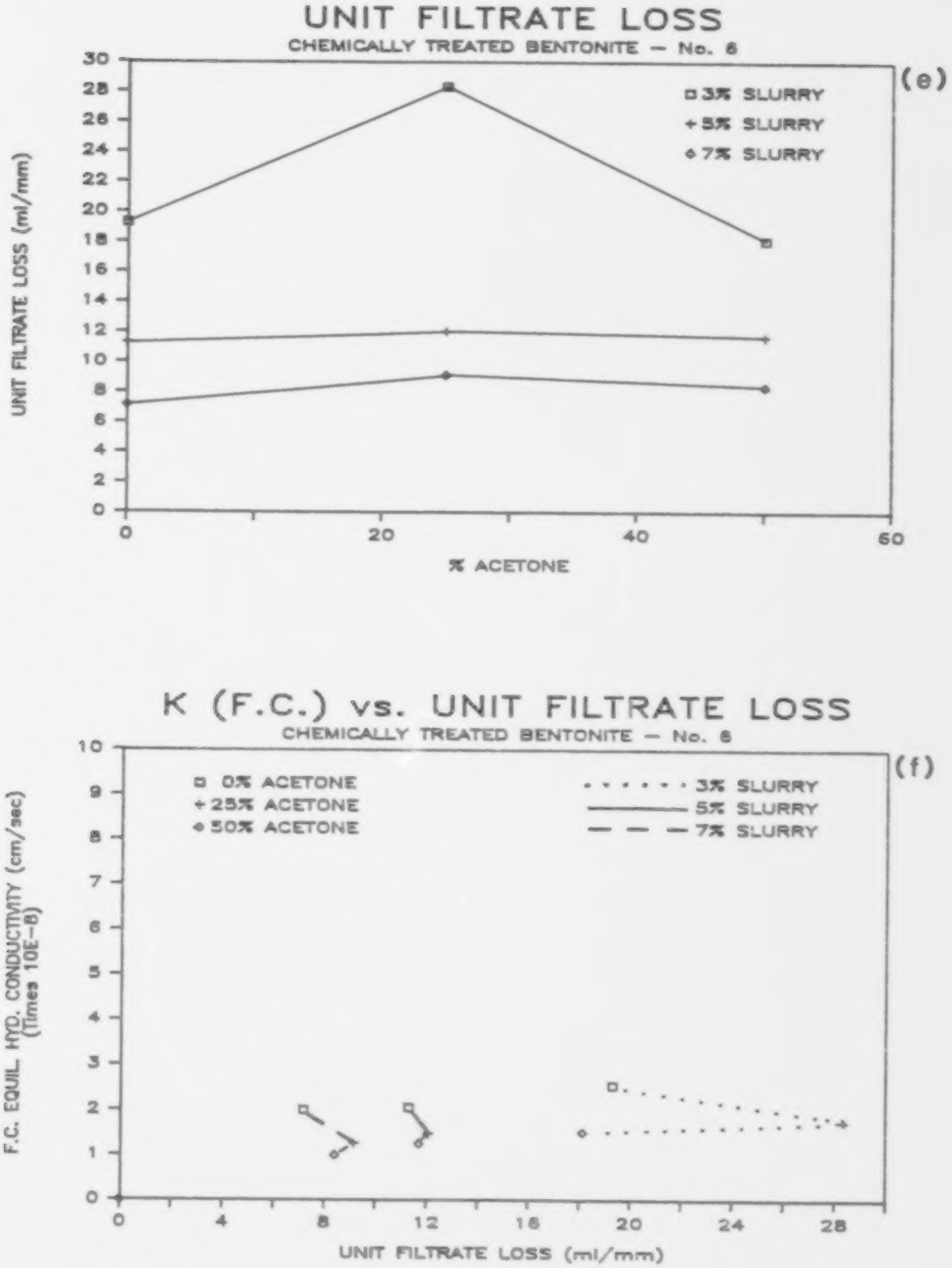


Figure C-26 contd.; (e) Phase III Unit Filtrate Loss test results.
(f) Correlation between indicator parameter and hydraulic conductivities of bentonite filter cakes.

APPENDIX D

STANDARD LABORATORY PROCEDURES

SLURRY MIXING PROCEDURE

(Powdered Bentonite)

EQUIPMENT:

electric stirrer and stand
2000 ml beaker
stopwatch (accurate to 0.1 sec)
balance (accurate to 0.01g)
1000 ml graduated cylinder
spatula

PROCEDURE:

To mix a 5% bentonite slurry (weight:volume basis):

1. a. A 5% bentonite slurry is defined as 100.0 grams oven-dry bentonite in 2000 ml total liquid volume (TLV) of water or water:chemical mixture (per applicable experimental design):

$$\frac{100.0\text{ g}}{2000.0\text{ ml TLV}} = 0.05\text{ g/ml} = 5\%$$

NOTE: Concentrations other than 5% or slurry volumes other than 2000 ml defined on same basis.

b. Bentonite for testing purposes should never be oven-dried; an "equivalent dry weight" (EDW) is determined on the basis of the moisture content of a representative sample as described below.

2. Component Proportioning:

a. Determine water content (w%) of air-dry bentonite per SLP No. G-01.

b. Determine EDW of air-dry bentonite as : EDW = 100.0 (1 + W%).

c. Determine volume of water (V_w) in EDW sample as V_w = 100 (w%) (weight = volume assumed).

d. Determine additional liquid volume (ALV) required for mixing as: ALV = 2000 - V_w.

Example: a. w% = 0.11 (decimal basis)
b. EDW = 100.0 (1 + w%) = 100.0 (1.11) = 111.0 g
c. V_w = 100 (w%) = 100 (0.11) = 11.0 g
d. ALV = 2000 - V_w = 2000 - 11.0 = 1989 ml

3. Decant the ALV of deionized water, selected test chemical, or water: chemical mixture into 2000 ml beaker.

4. Position lab stirrer and stand with paddle blade about 1/2" to 1" off bottom of beaker and slightly off center of beaker[1].

5. Start lab stirrer and add bentonite to water gradually over a three-minute period. Dispense bentonite directly into vortex created in beaker[2].

6. After all bentonite is added, continue stirring to a total mixing time[3] of five minutes.

7. Decant slurry and visually check beaker for significant bentonite residue or lumps. If significant bentonite remains in the beaker, repeat steps 5 - 7.

8. Store slurry undisturbed in moisture room (use storage time per applicable experimental design).

FOOTNOTES:

[1] This paddle height facilitates mixing, and being off-centered decreases the chances of bentonite being lost to stirrer rod and paddle blade.

[2] Bentonite can be added by convenient means, i.e., via spatula, a clean, dry funnel, etc. Adding the bentonite into the vortex facilitates mixing and decreases the chance of bentonite sticking on stirrer rod and paddle blade.

[3] At this time, the paddle blade may be centered in the beaker, if desired. The total mixing time should be doubled for granular bentonite to enhance mixing.

REFERENCE: Center Hill in-house procedure

SLURRY MIXING PROCEDURE

(Hydrated Bentonite Paste)

EQUIPMENT:

electric stirrer and stand
2000 ml beaker
stopwatch or timer
2000 ml Nalgene container
balance (accurate to 0.01g)
1000 ml graduate cylinder
spatula
500 ml wash bottle

PROCEDURE:

NOTE: This procedure for preparation of weight:volume chemical-bentonite slurries using water-hydrated bentonite paste. Mixing should be done in Hazardous Waste Lab (one-pass air, room 130) using applicable safety equipment and procedures.

1. Determine water content of selected bentonite paste per SLP No. G-01 (if not pre-determined by at least four separate measurements).

2. Based on water content results, weigh out quantity of paste equivalent to 100 grams dry bentonite (B_d).

3. Based on water content results, compute quantity of "available" water in bentonite paste sample (W_b).

4. Determine total water volume (W_T) and total chemical volume (C_T) required for 2000 ml final volume of desired slurry.

   Example: test slurry = 5% bentonite in 25% acetone. W_T = 2000 ml x 0.75 (proportion of water) = 1500 ml. C_T = 2000 ml x 0.25 = 500 ml.

5. Subtract quantity of water in paste sample (W_b) from total water required (W_T) to give volume of mixing water (W_m).

6. Decant roughly three-fourths of computed W_m into 2000 ml beaker, pour remainder of W_m into clean, dry 500 ml wash bottle.

7. Position lab stirrer and stand with paddle blade about 1/2" to 1" off bottom of beaker and slightly off center of beaker.

8. Start stirrer and slowly add equivalent dry bentonite quantity (B_d) using spatula.

9. After B_d has been added to the extent practical, carefully wash weigh boat and spatula with remainder of mixing water volume (W_m, step 6), taking care that all washings are directed into the 2000 ml beaker.

10. Decant remainder of mixing water (W_m, if any) into 2000 ml beaker and start timer.

11. Continue stirring for a total of 10 minutes; add total chemical volume (C_T) during final two minutes (to minimize evaporative losses).

12. Decant slurry and visually check beaker for significant bentonite residue or lumps. If significant bentonite remains in beaker, repeat mixing (step 11).

13. Decant thoroughly mixed slurry into Nalgene storage container, place in moisture room and leave undisturbed for 24 hours (or other storage/hydration time per applicable experimental design).

REFERENCE: Center Hill in-house procedure.

SLURRY RE-MIXING AFTER HYDRATION

EQUIPMENT:

electric stirrer and stand
2000 ml beaker
hydrated slurry mixture
stopwatch (accurate to 0.1 sec)

PROCEDURE:

To re-mix a bentonite slurry after hydration:

1. Shake slurry container to suspend any sediment.

2. Decant slurry into clean, dry 2000 ml beaker. Step 1 may have to be repeated intermittantly.

3. Position lab stirrer, stand, and beaker containing slurry with paddle blade 1/2" - 1" off bottom of beaker per SLP No. 01.

4. Start lab stirrer and mix slurry for at least five minutes. Greater mixing time may be required if slurry has gelled during storage. Mixing time should be identical for all slurries of the same bentonite concentration.

REFERENCE: Center Hill in-house procedure

2% SOIL/BENTONITE BATCHING PROCEDURE (20 lb.)

EQUIPMENT:

scale (accurate to .1 lb.)
mixer
1000 ml and 100 ml graduated cylinders
spatula

PROCEDURE:

1. Determine moisture content of bentonite (wb) per SLP No. G-01.
2. Weigh 20 lbs. of previously mixed Center Hill #2 soil (50% Bushelman medium sand, 20% F-95 Ottawa sand, 20% Center Hill clay, 10% Este sand).
3. Weigh equivalent of .4 lbs. of bentonite [$Wb = .4(1 + wb)$]. The weight of water in the bentonite is $Wwb = Wb - .4$.
4. Thoroughly blend soil and bentonite in mixer for five minutes.
5. To achieve 26% water content in soil-bentonite, add ($5.2 - Wwb$) lbs. of deionized water (1 liter = 2.2 lbs.).
6. Test actual moisture content per SLP No. G-01.
7. Label and store sample in moisture room.

REFERENCE: Center Hill in-house procedure

SPECIFIC CONDUCTANCE QC CHECK

Two QC samples will be run whenever any data is generated. These QC check samples will be analyzed before any samples are analyzed. If the expected results are not obtained, no samples will be run until the problem can be identified and corrected.

QC SAMPLE PREPARATION

Place approxiately 2 g of anhydrous KCl in a small beaker (100 ml) in a 103°C oven for at least 24 hours. Remove from oven and place in desiccator for 1/2 hour to cool to room temperature. Dissolve 745.6 mg of the KCl in the purest laboratory water available and dilute to 1000 ml in a volumetric flask. Transfer to a glass-stoppered glass bottle and clearly mark as follows:

0.0100N KCl

745.6 mg/l

conductivity = 1413 μ℧/cm

DATE:__________ INITIALS__________

This QC sample may be stored and used until either insufficient volume remains OR the sample is over 3 months old.

Prepare a second QC sample by carefully pipeting 10 ml of the .0100N KCl into the purest laboratory water available and dilute to 1000 ml in a volumetric flask. Clearly mark this flask as follows:

0.0001N KCl

conductivity = 14.94 μ℧/cm

DATE:__________ INITIALS:__________

This sample must be prepared fresh with each analysis.

Using the specific conductance SLP and the associated data sheet, measure the conductivity of both QC samples. If either one of the QC samples fails to give the expected results, the analysis must be stopped and corrected before any data can be generated.

Acceptable Range

1413 μ℧/cm 1398 - 1428

1413 ±1% meter accuracy ±1 for possible conductivity of water

14.94 μ℧/cm ±4 meter accuracy ±1 for possible conductivity of water

10 - 20

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DEIONIZED WATER CHECK

DATE	INITIALS	TEMP (°C)	CONDUCTANCE (μmhos) (uncompensated)	CONDUCTANCE (μmhos) (temperature comp.)

ALL CHECKS DONE WITH A TEMPERATURE COEFFICIENT SETTING OF 2.0
RANGE SWITCH SETTING OF 2 μmhos

LABORATORY SLUMP EQUIVALENT

EQUIPMENT:

- slump cone
- rod
- funnel
- soil pan
- calipers
- sand cone
- rigid mold compaction base
- 2 wing nuts
- cross bar
- ruler
- 10W40 spray oil
- large mixer
- stop watch
- hand scoop
- water wash bottle

SLURRY MIXING PROCEDURE:

5% slurry - Follow standard mixing procedure, SLP No. S-01.

10% slurry - Follow standard mixing procedure, but double the mixing time.

NOTE: Allow slurry to hydrate for 24 hours prior to using, or other time interval per applicable experimental design.

S/B MIXING PROCEDURE:

1. Add 30 pounds of dry C.H. #1 soil (67% clay, 33% sand) to mixing bowl.
2. Add the required amount of slurry to the soil over a 3-5 minute interval while the mixer is running at speed #1.
3. Determine amount of water needed to approximate desired slump. Add water by filling wash bottles and squirting the water into the center of the mixing bowl. Allow S/B to mix for at least an additional 15 minutes after all of the H_2O has been added.
4. After 15 minutes remove mixing blow from mixer. With a spatula, scrape the sides and the bottom of the bowl to loosen any dry soil that may be sticking to the inside of the bowl.
5. Allow S/B to mix for an additional 15 minutes.
6. Once mixing is completed, allow sample to hydrate in moisture room for a length of time per the applicable experimental design.

SLUMP EQUIVALENT PROCEDURE:

1. Invert small sand cone and set it on top of the bottom side of a clean moisture tin.

2. Spray a light coating of oil inside of the cone.

3. With a spatula fill the cone to 1/3 its volume. Rather than rodding the sample, hold the cone down and apply a slight pressure to the sample with the broad side of the spatula. Repeat this procedure two more times. Strike off excess S/B with spatula blade.

4. Dampen compaction mold base with H_2O and place the center of the base over the bottom of the cone. Turn mold base and cone over and slide moisture tin off. Make sure cone is full.

5. Screw wing nuts onto mold base and slide crossbar down to the top of the cone.

6. Adjust wingnuts so the bar rests on top of the cone.

7. Remove bar.

8. Slide cone straight up with no torsional motion. Remove cone within 2-3 seconds.

9. Replace crossbar and measure slump with depth gauge.

   NOTE: Be sure to subtract the thickness of the depth crossbar from the gauge reading to determine slump. When using depth gauge to determine slump, take ≈5 readings and average them to determine slump.

NOTES:

- For best results, try to obtain 2-,4-,6- and 8-inch slumps for the 1, 3, and 5 percent S/B mixtures. Do not attempt to predetermine water contents because 1, 3, and 5 percent S/B all have different W% for identical slumps.

- Immediately after running slump test, put the leftover S/B in a container with a lid and store it in a moisture room.

- For the 24-hour and 1-week tests, make sure the S/B is mixed thoroughly before running the slump tests, since the water tends to separate from the S/B over time.

- Each time a set of slump tests are done (3 slump cone tests and 3 sand cone tests), at least 3 water content tests should be taken. This is done to verify that the water content of a particular sample is remaining constant.

- After every slump trial the cone and soil pan must be washed off. After every trial with the sand cone, the cone and base must be washed.

- After running a sand cone trial, discard the S/B used in that trial so that the oil does not contaminate the S/B used for future tests.

- To determine W%, average the W% from both the slump test and sand cone tests.

- To determine slump, average the three slumps.

MODIFIED SWELL TEST

EQUIPMENT:

- consolidometer frame
- consolidometer dial gauge
- floating ring consolidometer
- consolidation ring
- 2 porous stones
- 2 filter papers
- balance accurate to 0.01 g
- fume hood (or equivalent)
- 250 ml beaker
- 8" evaporation dish
- metal spatula
- airtight container
- weigh boats
- timer
- mortar
- pestle

PROCEDURE:

1. Obtain approximately 40 grams of "air dry" bentonite powder.

2. Determine the water content of approximately 20 grams of the bentonite powder per SLP No. G-01.

3. Place one porous stone in the consolidometer. Fit the consolidation ring around the stone. Place one filter paper within the ring on the stone (trim paper to fit if necessary).

4. Weigh out 20 grams "equivalent dry weight" of the remaining bentonite powder in a tared weigh boat and spoon into the consolidation ring. Level with metal spatula.

5. To level sample completely, drop floating ring assembly five times from a height of approximately 1/2 inch.

6. Place the other filter paper (trimmed) within the ring on top of the leveled sample. Then place the second porous stone on top of the filter paper, alignment hole up.

7. Place the consolidometer on the rigid base of the consolidation frame. Center the consolidometer such that the tip of the dial gauge stem will rest in the alignment hole of the top porous stone when lowered. Record initial dial gauge reading.

8. Fill the consolidometer with deionized water just to the top of the consolidation ring. Start the timer and record initial dial reading when the bentonite starts to swell as indicated by initial movement of the dial gauge.

9. Take a reading once every hour for seven hours.

10. With every reading, check the water level and adjust, if necessary, so that it remains at the top of the consolidation ring.

11. After seven hours, extract the sample from the ring and inspect the porous stone and ring for signs of "binding" or other problems which might affect swell values.

12. Plot raw data as inches swell versus time in hours.

13. Repeat steps 1-12 for the same bentonite, modifying step 1 for the chemical "modification" tests as follows:

    a. Place 40.0 g "equivalent weight" bentonite in a 250 ml beaker. Add 50 ml chemical and mix thoroughly using metal spatula (additional chemical may be added if needed to completely saturate the bentonite, but the total volume of chemical per test should be held constant if multiple tests are planned).

    b. Pour bentonite/chemical slurry into 8" evaporation dish and place in fume hood until all chemical has volatilized (usually 24 hours).

    c. After chemical volatilization, obtain 20.0 g of "volatilized" bentonite powder for test. Pulverize dry "volatilized" bentonite lumps as necessary using a mortar and pestle.

NOTE: In some cases, chemical may not completely volatilize even after extended fume hood drying. In such cases, discard unvolatilized bentonite (wet or pasty consistency) and proceed if there remains sufficient "volatilized" bentonite.

ALSO: It has been demonstrated that the rate of swell and the total 7-hour swell value of a typical (unaltered) bentonite in baseline (water only) tests is a function of the initial "air dry" water content. For comparisons between different bentonites, therefore, it is necessary to precondition the various bentonites to the same initial "air dry" water content before testing. This is most readily accomplished by drying the relatively "wet" bentonites down to the "air dry" water content of the driest sample to be tested. Drying should be accomplished using an evaporation dish in a low humidity environment. (Do NOT use SLP No. G-01.) In any case, the "air dry" water content of the different bentonite samples should not vary by more than 1 percentage point. An initial "standardized" air dry water content under 10.0% is recommended.

SLP No. EX-03
Revision 0-061986
Sheet 1 of 2

FILTER CAKE HYDRAULIC CONDUCTIVITY: API FILTER PRESS

EQUIPMENT:

standard API filter presses
25 ml graduated cylinders
dial or vernier calipers
timer
filter paper (Dresser-Magcobar 2-189 or equivalent)
spatula

PROCEDURE:

A. Prepare bentonite slurry per SLP S-02.

B. Allow slurry to hydrate undisturbed for 24 hours (or other, per applicable experimental design) in moisture room.

C. (OPTIONAL) Re-mix slurry per SLP S-03 if necessary to achieve uniform mix.

1. Assemble filter press cell in the following order: base cap, rubber gasket, screen, filter paper, rubber gasket, and filtrate cylinder.

2. Fill the cylinder with slurry to within 1/4" of the top and place in filter press frame.

3. Position top cap (connected to pressure source) with rubber gasket in place on the filter press cell and secure with T-screw.

4. Place a clean, dry 25 ml graduated cylinder under the filtrate drain on the support stand.

5. Close the in-line valve, open the cell pressure valve, close the cell bleed valve, and adjust the regulator to 100 psi.

6. Open the in-line valve and start timer.

7. (OPTIONAL) Record the volume of filtrate collected at 7.5 minutes elapsed time. (This amount doubled should be a close estimate of the 30-minute filtrate volume.)

8. Record the volume of filtrate collected at 30 minutes total elapsed time.

9. Close in-line valve, open bleed valve to remove system pressure, and close the filter press cell pressure valve.

10. Loosen the T-screw, remove the cell top cap, remove cell from frame and decant slurry.

11. Fill the cell with the aqueous organic permeant to within 1/4" of the top and place in filter press frame with 0-30 psi regulator.

12. Reposition top cap on the filter press cell and secure cell with T-screws.

13. Place a clean, dry 25 ml graduated cylinder under the filtrate drain on the support stand.

14. Open the cell pressure valve with the cell bleed valve open and adjust regulator to the desired pressure.

15. Close cell bleed valve and commence timing.

16. Periodically measure and record effluent volume and elapsed time, refilling cell with permeant if necessary.

17. After desired testing period, measure and record final effluent volume and elapsed time.

18. Close the cell pressure valve, open bleed valve to remove system pressure, and shut off pressure at (wall) regulator.

19. Loosen the T-screw, remove cell from the frame, and decant permeant into approved container.

20. Disassemble filter cell and remove filter paper on which filter cake has been formed.

21. Remove excess slurry from filter cake with a gentle stream of water, then measure and record filter cake thickness (mm).

22. Calculate and record the permeability (k) of the filter cake using Darcy's equation ($Q = kiA$).

SOIL-BENTONITE HYDRAULIC CONDUCTIVITY: API FILTER PRESS

EQUIPMENT:

Standard API Filter Press
Graduated Cylinders
Bentonite Paste
Medium Sand
Vernier Calipers
Scale (accurate to .1g)
Machined Plexiglass Discs
Consolidation frame & boxes
Spatulatas
Timer/Clock

PROCEDURE:

A. Prepare soil-bentonite backfill per SLP S-04 A.

1. With vernier calipers, measure the diameter of the API filter press cell and calculate its cross-sectional area.

2. Calculate the surcharge weight necessary to consolidate sample at 5 psi.*

3. Assemble the filter press in the following order: base cap, rubber gasket, screen, rubber gasket and filter press cell.

4. Measure the distance from the top of the filter press cell, to the screen on the base cap (D_1).

5. Remove the filter press cell and apply a thin (approx. 1/32") film of fully hydrated bentonite paste to the inner wall of the cell, extending about 2-1/4" up the side of the cell.

6. Reassemble the filter press cell.

7. Carefully place a thin layer (1/16" ±) of medium sand on the screen, spreading and "rodding" the sand to ensure good contact between the sand and the cell wall.

8. With the plexiglass disc, tamp the sand to level, remove large void spaces, and consolidate.

9. Measure the distance to the top of the sand (D_2) with the calipers.

10. Calculate the thickness of the sand layer (H_{sand}) as:

$$H_{sand} = D_1 - D_2$$

11. Repeat steps 7-10 until the sand layer is approximately 1/4" thick.

---

*Per applicable experimental design

12. Weigh the cell + paste + sand to nearest 0.1g.

13. Carefully spoon the soil-bentonite into the cell in thin lifts approximately 1/2" thick.

14. Spread and "rod" the soil-bentonite to achieve good backfill-cell contact and minimize artificial void space (air bubbles).

15. Tamp the soil-bentonite with the plexiglass disc to level it, and further minimize artificial void space.

16. Measure the distance to the top of the soil-bentonite (D_3) and calculate the height of the soil-bentonite layer as:

$$H_{s-b} = D_2 - D_3$$

17. Repeat steps 12-15 until the soil-bentonite is approximately 2" deep.

18. Weigh the cell + paste + sand + backfill, and compute the weight of the soil-bentonite (re. step 12).

19. Place the soil-bentonite filled cell in the consolidation frame.

20. Fill the consolidation box with enough sand to allow for 5 psi* consolidation, and place on the API cell using the plexiglass load disc, ball bearing and plexiglass rod to support the consolidation box.

21. Record the initial scale reading on the side of the consolidation box when the weight initially contacts the sample.

    Note: Steps 20 and 21 generally require coordination of activities between two assistants.

22. Consolidate the sample for 48 hours.*

23. After consolidation, record the final scale reading, calculate the total consolidation and remove the consolidation box.

24. Remove the plexiglass disc from the cell.

25. Measure and record the post-consolidation height of the soil-bentonite for use in computing hydraulic gradient.

26. Weigh the cell and sample.

27. Place the cell on the filter press frame, fill with the desired permeant, attach the cell cap, open the air source and valves and begin permeating at 2 psi.*

28. Approximately 24 hours* later, increase the pressure to 3 psi.*

---

*Per applicable experimental design

29. After 24 hours*, increase the pressure to 4 psi*, recording the date and time when permeating at 4 psi* began.

30. Periodically measure and record the effluent volume (Q) and elapsed time, refilling the cell with permeant as necessary.

31. Calculate hydraulic conductivity (k) at each reading as: k=Q/iA; using individual* or cumulative* filtrate and time values.

32. After the desired testing period*, or attainment of study state (equilibrium) conditions*, or passage of the specified minimum pore volumes*, calculate and record a final hydraulic conductivity value.

33. Close the cell pressure valve, open the bleed valve to remove the system pressure, and close the in-line valve.

34. Remove the cell from the frame and decant any unused permeant into an approved container.

35. Weigh the sample and cell and determine the final total weight of the soil-bentonite sample.

36. Extract the soil-bentonite sample and take a representative sample for a moisture content determination, per SLP G-01.

37. Dispose of the remaining soil-bentonite per applicable disposal procedure.

---

*Per applicable experimental design

REF: Center Hill in-house procedure

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Sheet 1 of 1

WATER CONTENT

EQUIPMENT:

balance (accurate to 0.01g)
drying oven
dessicator
moisture tins

PROCEDURE:

1. Weigh moisture tin; record tare weight in grams (T).
2. Weigh wet soil plus tin; record in grams (W).
3. Oven dry overnight to a constant weight at a temperature of 105°C ± 3°.
4. Allow tin to cool in dessicator for 15 minutes. Weigh and record in grams (D).

CALCULATIONS:

$$\text{Percent Moisture} = \frac{(W - D)}{(D - T)} \times 100$$

SPECIAL NOTE:

For soils treated with flammable chemicals, sample should be air-dried in fume hood 24-hours before oven drying (Step 3).

REFERENCE: API RP 13A, Tenth Edition, Sec. 4.6/Center Hill in-house.

SPECIFIC GRAVITY OF SOLIDS, G_s

EQUIPMENT:

500 ml volumetric flask
vacuum pump and 1/4" tubing
soil drying oven
balance (sensitive to 0.01 g)
thermometer (accurate to 0.1°C)
evaporating dish
water bath (sink)

PROCEDURE:

A. Flask Calibration: all specific gravity tests

1. To a clean flask, add de-aired distilled water at room temperature until the bottom of the meniscus is at the calibration mark on the flask.

2. Carefully dry the outside of the bottle and the inside of the neck above the water surface.

3. Measure water temperature to 0.1°C at several positions in flask. If water temperature varies with elevation, agitate flask to promote mixing and temperature equilibration. Record equilibrated temperature.

4. Weigh bottle plus water to 0.01 g; record.

5. Repeat Steps 1-4 at about 4°C below room temperature (water bath cooling prior to Step 2) and about 4°C above room temperature (warm water bath or gentle heating over flame). In each case, add or remove water to the calibration mark before measuring temperature and weight.

6. Plot calibration curve consisting of at least three weight/temperature measurements; store calibration curve on file for future reference.

B. Specific Gravity: Typical Soils

1. Determine water content of soil per SLP No. G-01.

2. Add quantity of moist or damp soil equivalent to oven-dried weight of 50 grams (cohesive soil) or 150 grams (cohesionless soil) to evaporating dish and sufficient de-aired, deionized water to form a slurry.

3. Transfer slurry to 500 ml flask. Using wash bottle, wash evaporating dish to insure collection of all soil. Add de-aired, distilled water until flask is about half full. Slowly agitate (mix) contents for 3 minutes.

4. Connect flask to vacuum line and evacuate flask for 4 hours (cohesive soils) or 1 hour (cohesionless soils), gently agitating the flask several times during this procedure to promote removal of entrapped air.

5. After proper evacuation, fill flask with de-aired, deionized water until the bottom of the meniscus is coincident with the calibration line on the neck of the flask.

6. Thoroughly dry the outside of the flask and remove moisture on the inside of the neck using a paper towel. Take care not to contact meniscus with towel.

7. Weigh flask and contents to nearest 0.01g. Record on data sheet, line 4.

8. Agitate suspension to assure uniform temperature and measure temperature of suspension to nearest 0.1°C with thermometer at mid-depth of flask.

9. Carefully transfer all flask contents to large evaporting dish. Use wash bottle to ensure collection of all soil.

10. Oven-dry sample to a constant weight at 110°C ±3C, allow soil to cool at room temperature in dessicator, weigh the dry soil to 0.01 g. Record as weight of dry soil, W_s, on data sheet, line 10.

11. Obtain weight of "flask plus water" at the temperature measured in Step 8. Record on data sheet, line 6.

12. Obtain water relative density and temperature correction factor (α) from Corps of Engineers Laboratory Soils Testing Manual, Table IV-1, page IV-8.

13. Compute specific gravity, G_s, per data sheet as:

$$G_s = \frac{\alpha W_s}{W_w}$$

C. Specific Gravity: Bentonites

The following modifications of standard procedure apply to bentonites only. Steps 1-13 for typical soils apply, except as follows:

2. Use 15.0 grams equivalent dry weight; add bentonite slowly to promote thorough mixing.

4. Evacuate flask overnight to achieve adequate removal of entrapped air and allow for bentonite hydration.

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GRAIN SIZE ANALYSIS

(Mechanical, Hydrometer, Combined)

EQUIPMENT:

U.S. Standard Sieves: Nos. 4, 10, 20, 40, 100, 200, pan
mortar and pestle
balance (sensitive to 0.1 g)
sedimentation cylinders (1000 ml, graduated)
hydrometer: No. 151H or equivalent for general soils testing
 No. 14 331 5B for bentonite slurry
soil dispersion mixer and baffeled mixing cup
soil dispersant: $NaPO_3$ (Calgon)
thermometer (sensitive to 0.1°C)
timer and stopwatch
wash bottle

GENERAL OUTLINE:

This SLP is intended to apply to a mechanical analysis (gravel and sand, e.g. coarser than No. 200 sieve), a hydrometer analysis (silt and clay, e.g. finer than No. 200 sieve), or a combined total analysis (gravel-sand-silt-clay mixtures). With minor modification as noted herein, the procedure may also be applied to bentonite slurries of low concentration (generally 1% bentonite).

For the sake of procedural consistency and clarity, this SLP has been developed in conjunction with the applicable data forms. Test results are reported on a separate grain size distribution plot (standard C.H. form).

The test procedure with corresponding data forms is separated into four parts:

Part 1. Mechanical Analysis Procedures

Part 2. Hydrometer Analysis Procedures

Part 3. Worksheets

Part 4. Appendix - Calibrations and Constants

PART 1

A. Mechanical Analysis:

1. Obtain approximately 500 g of representative soil sample; air dry sample and pulverize silt and clay lumps using mortar and rubber-tipped pestle.

2. Carefully wash sample on clean No. 200 sieve; place +200 fraction in oven to dry overnight.

3. Determine weight of washed, oven-dried +200 sample; enter as "W_T" on Sheet 7.

4. Assemble selected sieve stack, plus pan; pour sample on top sieve; cover and secure sieve stack in shaker; shake for 10 minutes at medium speed.

5. Place large aluminum pan on triple beam balance; determine tare weight, grams; enter tare weight in Sections 1 and 2, sheet 7.

6. Starting with top sieve (largest screen opening), carefully empty contents into aluminum pan, recording the cumulative weight total for each successive sieve. Data should be recorded in "cumulative weight retained" column of Sheet 7, Sections 1 and 2, as total weight including pan, followed by the net soil weight (e.g. 120.0/20.0 where pan tare = 100.0g).

7. For each sieve, compute cumulative % retained as the cumulative net weight retained, divided by W_3.

8. For each sieve, subtract cumulative % retained from 1.00; enter result as cumulative % finer.

9. Plot cumulative % finer results on standard C.H. grain size distribution form, noting all pertinent sample classification and identification information.

PART 2

B. Hydrometer Analysis: Typical Soils and Liquids

1. Determine composite correction for temperature, meniscus, deflocculant and chemical per Appendix Sheets A-1 and A-2 (if not already performed and on file for the test conditions selected).

2. Calibrate hydrometer to determine depth to center of bulb as per Appendix Sheet A-4 (if not already performed and on file for the hydrometer to be used).

3. Prepare fresh 4% deflocculant solution by mixing 40.0 grams deflocculant with 960 ml of deionized water.

4. Oven-dry soil sample, collect -10 sieve fraction, and weigh out exactly 50.0 g. Thoroughly mix with 125 ml of 4% deflocculant solution, cover and allow to stand 24 hours.

5. Transfer mixture into soil dispersion cup and add deionized water until cup is about two-thirds full; mix for three minutes.

6. Decant mixture into 1000 ml sedimentation cylinder, taking care to wash all sediment from cup with wash bottle; add additional deionized water up to 1000 ml mark.

7. Prepare control cylinder consisting of 125 ml deflocculant solution and 875 ml deionized water in 1000 ml graduate.

8. Place hydrometer and thermometer in control cylinder and allow control cylinder and sedimentation cylinder temperatures to stabilize and equilibrate.

9. Place palm of hand tightly over top of sedimentation cylinder and repeatedly agitate by turning cylinder upside down until all sediment is suspended (typically one minute).

10. Place sedimentation cylinder on counter at start of test (time "zero"), immediately insert hydrometer and take readings at 30 sec, and 1, 2, 3, 4 minutes total elapsed time. Record on hydrometer worksheet, Sheet .

11. Repeat Steps 8 and 9 until agreement is obtained for readings during the first four minutes; take temperature of suspended solution.

12. Repeat Step 8. Take only 4-minute readings. Continue test, taking readings at 8, 15, 30, and 60 minutes and 2, 4, 8, 16, 32, and 64 hours, total elapsed time, recording temperature with each hydrometer reading.

13. For each reading, enter the following on the worksheet:

    C_C - composite correction for test conditions (to be established prior to test per Appendix sheets A-1 and A-2)

    K - composite viscosity, temperature and specific gravity correction, from Table I (Appendix Sheet A-3)

    L - depth value to center of hydrometer bulb, cm, from hydrometer calibration (Appendix Sheet A-4).

14. Compute particle diameter in millimeters (D) and percent suspended (W_T%), record on worksheet and Sheet 7, Section 3.

15. After all readings have been taken, agitate sediment as in Step 8; pour over No. 200 sieve. Wash bottle repeatedly as necessary to insure collection of all sediment from cylinder.

16. Wash material retained on NO. 200 sieve (if any) into aluminum weigh pan, oven dry for 24 hours at 105°C ±3C.

17. Sieve +200 fraction in No. 4, 10, 20, 40, 100, 200 sieves per Step A-4 (mechanical analysis), compute cumulative % retained and cumulative % finer per mechanical analysis procedure, using 50.0 grams as total original soil weight.

18. Plot cumulative % finer results on standard C.H. grain size distribution form, noting all pertinent sample classification and identification information.

C. Hydrometer Analysis: Bentonite and/or Chemicals

The following modifications of the "typical" hydrometer procedure are required for testing bentonites or other testing involving liquids other than deionized water.

a. Use 10.0 grams bentonite in Step B-4.

b. Prior to Step B-4, transfer mixture into graduate cylinder and add additional deionized water up to a total volume of proportion to 1000 ml of final bentonite/chemical mix (e.g. if test calls for 75% acetone slurry, add water to 250 ml mark during this step). Then transfer mixture into soil dispersion cup, mix for three minutes and decant into sedimentation cylinder. Transfer and mix in several steps if necessary due to large volume required when low chemical concentrations are being made.

c. When entire bentonite-deflocculant-deionized water mixture has been decanted into sedimentation cylinder, add selected chemical up to 1000 ml mark (instead of additional water per Step B-6) using appropriate safety procedures. Cap cylinder with parafilm to minimize evaporative losses.

d. Conduct test per remaining "typical" procedures B-7 thru B-18.

PART 3.

COMBINED ANALYSIS WORKSHEET

PROJECT NO ____________ SAMPLE NO. ____________ TEST NO. ____________

TEST TYPE ____________ DATE ____________ ANALYST ____________

I. **SAMPLE PREPARATION** Gross Sample: Grate soil sample (if clayey) or break up lumps and clods with hands. Air-dry gross sample, pulverize with mortar and rubber pestle. Separate on #10 sieve, work through by hand. Retain both fractions.

II. **+10 FRACTION**

Pan No. ______
Wt. oven dry soil & pan ______ g
tare ______ g
Wt. oven dry soil : W_1 ______ g

III. **-10 FRACTION**

Determine gross air dry weight. Back-figure gross "oven" dry weight using moisture content data determined in Step IVb.

Pan No. (sieve pan) ______
Wt. air dry soil & pan* ______ g
tare ______ g
Wt. air dry soil ______ g
Wt. "oven" dry soil : W_2 ______ g

IV. **-10 FRACTION: HYDROMETER ANALYSIS**

a. Split out representative portion from gross -10 fraction after Step III. (Use ~50 g for clays, ~100 g for sandy soils.)

Pan No. ______
Wt. air dry soil & pan* ______ g
tare ______ g
Wt. air dry soil ______ g
Wt. "oven" dry soil used in hydrometer test : W_0 ______ g

b. Obtain representative sample from remainder of -10 fraction. Use Sartorius balance to determine moisture content per SLP No. G-01. Calculate "oven" dry weights in III & IVa.

Where:

$$\text{"oven" dry} = \frac{\text{wt. air dry soil}}{1.0 + \text{moist. cont.}}$$

MOISTURE CONTENT

Tin No. ______
Wt. air dry soil & tin* ______ g
Wt. oven dry soil & tin ______ g
tare ______ g
Wt. water ______ g
Wt. dry soil ______ g

Moisture content: 0. ______

---

*Minimize time between these determinations

HYDROMETER ANALYSIS WORKSHEET

Project No.________ Sample No.__________ Test No.________ Test Type ________

Analyst __________________ Date _________________ Hyd. No.________________

Sample Description:____

Remarks:____

INITIAL DATA

deflocculant ___________________________
fluid medium ___________________________ Wt. soil used, W_O: _____________g
specific gravity, Gs____________________ (from sheet 5)

							SEE NOTE				
DATE	TIME	ELAPSED TIME (MIN)	READ	TEMP °C	C_c	R & C_c	L	K	D	W_T	RMK
		0.5									
		1									
		2									
		3									
		4									
		8									
		15									
		30									
		60									
		120									

NOTES: $D = K\sqrt{L/T}$, $W_T\% = \frac{100}{W_O}\,\frac{Gs}{Gs-1}\,(R + C)$

L from Appendix Sheet A-3, K from Appendix Sheet A-4

Test Type: X -10 fraction of total sample (combined)
Y -10 size = total sample (combined)
Z -200 size = total sample (hydrometer only)

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GENERAL GRAIN SIZE ANALYSIS WORKSHEET

Project No.________________ Sample No. ______________ Test No.___________
Test Type _________________ Date ____________________ Analyst ___________

W_T: Gross dry wt. total sample = $W_1 + W_2 = W_T$ = _____ + _____ = ________ g

SR: Sample ratio = W_2/W_T = ___________/__________ = _____________________

(combined analysis only; SR = 1.0 for M or H)

M = Mechanical, H = Hydrometer, C = Combined Analysis

M or C	SIEVE NO.	DIAMETER IN	DIAMETER MM	A CUM. WT. RETAINED	A/WT CUM. % RETAINED		CUM. % FINER
1. +10 fraction of gross dry sample.	-	3	76.1				
	-	2	50.8				
	-	1-1/2	38.1				
	-	1	25.4				
pan no.______	-	3/4	19.0				
tare ________g	-	1/2	12.7				
	-	3/8	9.5				
	4	.187	4.76				
	10	.079	2.0				

M or H or C				(M) → B/W_T (H or C) → B/W_o B		C CUM. % FINER	C x SR
2. -10 fract. of mech. anal. or +200 fraction after hydro. test.	20	.0331	.841				
	40	.0165	.420				
	100	.006	.149				
pan no.______	200	.003	.075				
tare________g W_o:_________g							

H or C	ELAPSED TIME MIN.	DIAMETER MM	D W%	D x SR
3. Hydrometer Test Results	0.50			
	1.0			
	2.0			
	5.0			
	15.0			
	30.0			
	60.0			
	120.0			

↑------------SUMMARY PLOT------------↑

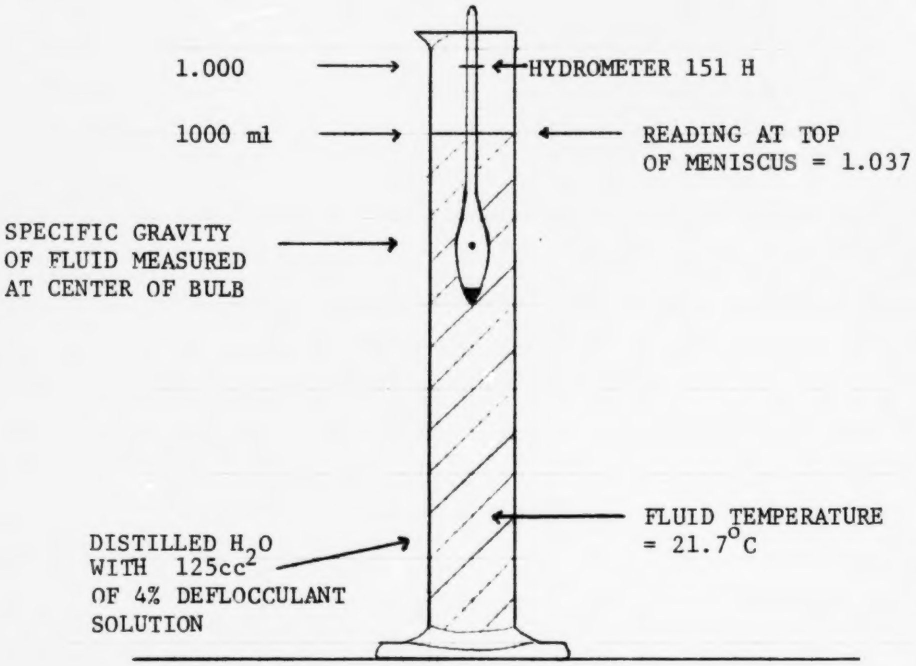
PART 4. APPENDIX

GRAIN SIZE ANALYSIS

Composite Correction

General: A separate calibration is required for each hydrometer/test liquid combination (water or chemical:water soil slurries). Calibration is performed to determine composite correction (C_c) for combined effects of meniscus, deflocculant, chemical and temperature. All C_c values should be rounded to the nearest tenth and subtracted from the raw hydrometer readings on the Hydrometer Analysis Worksheet.

Typical Calibration Set-up:


1.000
HYDROMETER 151 H
1000 ml
READING AT TOP OF MENISCUS = 1.037
SPECIFIC GRAVITY OF FLUID MEASURED AT CENTER OF BULB
FLUID TEMPERATURE = 21.7°C
DISTILLED H2O WITH 125cc OF 4% DEFLOCCULANT SOLUTION

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Sheet A-2

Typical Calibration Curve:

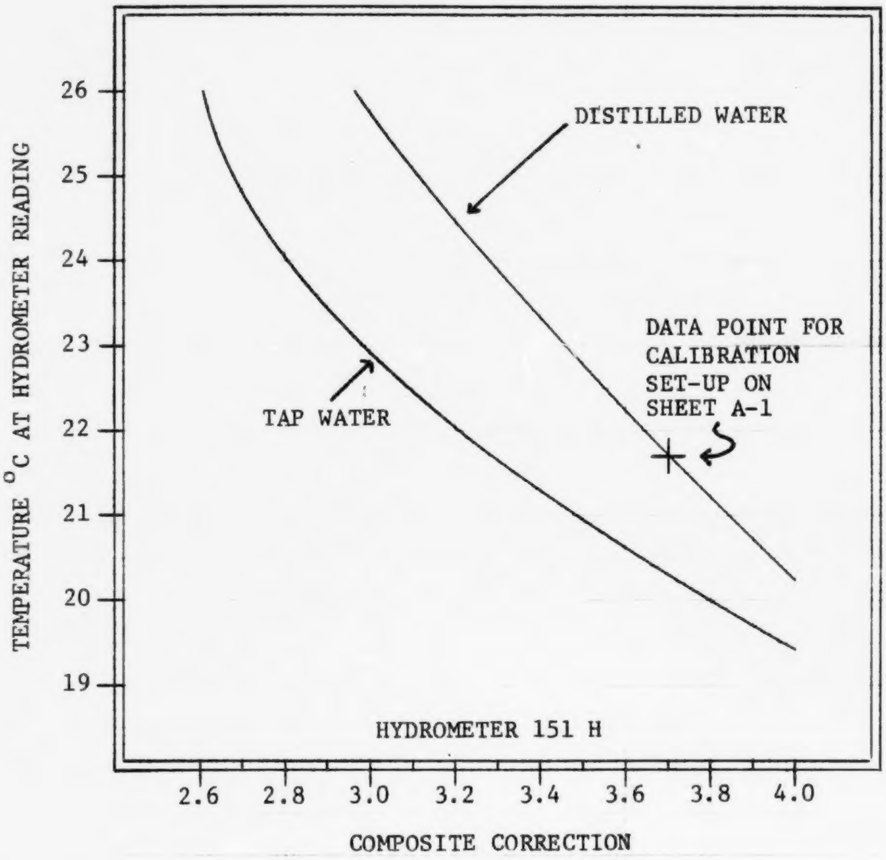
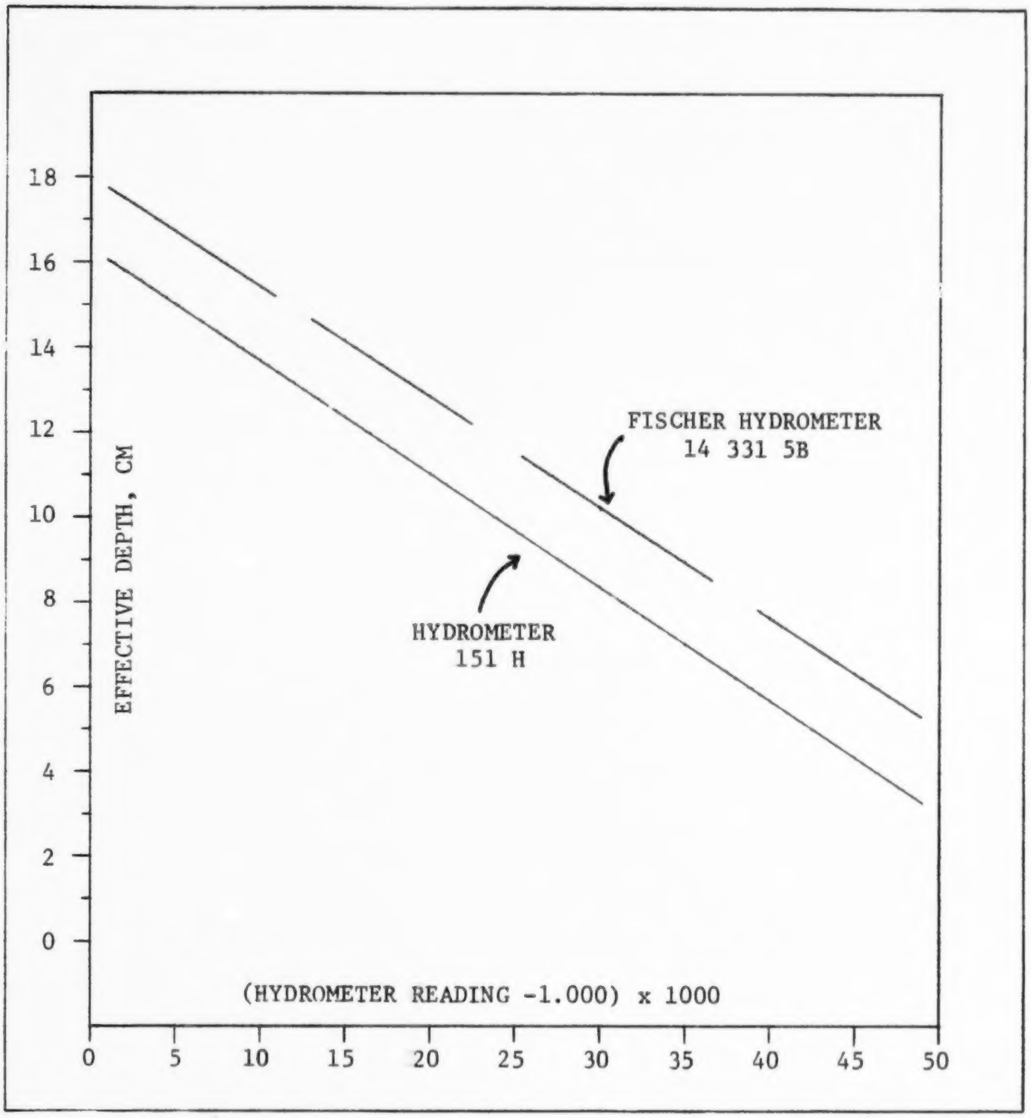


TABLE 1. VALUES OF K FOR USE IN EFFECTIVE DIAMETER COMPUTATION, SHEET 6.

Temp. (°C)	UNIT WEIGHT OF SOIL SOLIDS (g/cm³)							
	2.50	2.55	2.60	2.65	2.70	2.75	2.80	2.85
16	0.0151	0.0148	0.0146	0.0144	0.0141	0.0139	0.0137	0.0136
17	0.0149	0.0146	0.0144	0.0142	0.0140	0.0138	0.0136	0.0134
18	0.0148	0.0144	0.0142	0.0140	0.0138	0.0136	0.0134	0.0132
19	0.0145	0.0143	0.0140	0.0138	0.0136	0.0134	0.0132	0.0131
20	0.0143	0.0141	0.0139	0.0137	0.0134	0.0133	0.0131	0.0129
21	0.0141	0.0139	0.0137	0.0135	0.0133	0.0131	0.0129	0.0127
22	0.0140	0.0137	0.0135	0.0133	0.0131	0.0129	0.0128	0.0126
23	0.0138	0.0136	0.0134	0.0132	0.0130	0.0128	0.0126	0.0124
24	0.0137	0.0134	0.0132	0.0130	0.0128	0.0126	0.0125	0.0123
25	0.0135	0.0133	0.0131	0.0129	0.0127	0.0125	0.0123	0.0122
26	0.0133	0.0131	0.0129	0.0127	0.0125	0.0124	0.0122	0.0120
27	0.0132	0.0130	0.0128	0.0126	0.0124	0.0122	0.0120	0.0119
28	0.0130	0.0128	0.0126	0.0124	0.0123	0.0121	0.0119	0.0117
29	0.0129	0.0127	0.0125	0.0123	0.0121	0.0120	0.0118	0.0116
30	0.0128	0.0126	0.0124	0.0122	0.0120	0.0118	0.0117	0.0115

Hydrometer Calibration

General: Different hydrometers are required for the hydrometer analysis, depending upon the range of specific gravity likely to be encountered for a given test. The calibration below is for hydrometer 151 H (standard soils testing) and Fischer hydrometer 14 331 5B (1% bentonite slurries) and is used to determine the effective length (L) to the center of the hydrometer bulb for calculation of effective diameter (D) per the Hydrometer Analysis Worksheet (Sheet 6). If a different hydrometer is used, a separate effective depth calibration will be required per Corps of Engineers Laboratory Soils Testing Manual, Appendix V, Section 3-C.



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FREE SWELL

EQUIPMENT:

100 ml graduated cylinder
parafilm
balance (accurate to 0.01g)
weighing boats
thermometer (accurate to 0.5°C)

PROCEDURE:

1. Determine water content of "dry" bentonite per SLP No. G-01.
2. Fill graduated cylinder with 100 ml deionized water.
3. Weigh out 2.0 grams bentonite (dry weight basis) and sprinkle onto water surface in cylinder until surface is covered.
4. Add the entire 2.0 grams over a period of 30 minutes, letting each successive layer wet and settle.
5. Cover graduated cylinder with parafilm and allow to hydrate.
6. Measure volume of swelled bentonite (and temperature of water above bentonite) at 2 hours and 24 hours total elapsed time. Record as swell volume (ml) at corresponding time and temperature.
7. Discard bentonite and liquid per applicable safety procedures.

REFERENCE: U.S. Pharmacopoeia, 20th Revision/Center Hill in-house.

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Revision No. 0-022885
Sheet 1 of 2

UNIT WEIGHT

(Undisturbed Tube Sample)

EQUIPMENT:

steel sample tube
steel sample rod
steel extrusion rod
aluminum sample tray
dial calipers
balance sensitive to 0.01g
moisture content tin
drying oven
soil knife
flat-bottom sloop

PROCEDURE:

1. Select steel sample tube, determine tare weight to 0.01 g; record. Measure tube I.D. and length to 0.001", compute tube volume to 0.001 cm^3; record.

2. Prepare flat surface area on soil to be sampled using soil knife or flat bottom scoop (surface can be any incliniation per applicable experimental design, e.g. vertical vs. horizontal tube sample).

3. Affix tube to sample rod using rod pin, place tube perpendicular to fresh sample face and press tube into soil using steel sample rod and slow, continuous motion. Depth of penetration should be less than or equal to the tube length (e.g. do not over-penetrate and thereby disturb sample).

4. Allow tube to remain undisturbed for five minutes, then rotate sample rod and tube to shear soil at leading edge of tube, and slow extract sample rod and full tube. If soil is too soft to be recovered intact, it will be necessary to manually excavate around the tube and use a wide blade knife or flat bottom scoop to hold the sample in place during tube extraction.

5. Trim soil flush with sample tube, clean all soil from outside of tube, weight tube with soil to 0.01 g; record.

6. Using extrusion rod, slowly extrude sample toward rear (pin end) of tube. Receive sample in sample tray as it is extruded.

7. Carefully examine surface of extruded sample for disturbance due to gravel or coarse sand materials or general voids which would invalidate calculated sample volume. If sample is badly disturbed, discard and re-sample.

8. Slice sample lengthwise and inspect per Step 7.

9. Select representative portion of sample for water content determination per SLP No. G-01.

10. Calculate wet unit weight as: $$\frac{\text{wet sample weight, g}}{\text{sample volume, cm}^3}$$

Calculate dry unit weight as: $$\frac{\text{wet unit weight}}{1 + \text{water content}}$$

REFERENCE: Center Hill in-house procedure

SLP No. G-06
Revision 0.090385
Sheet 1 of 1

SLUMP TEST

EQUIPMENT:

slump cone
tamping rod

SAMPLE PREPARATION:

Prepare slump sample per slurry and soil-bentonite mixing procedures, if applicable.

PROCEDURE:

1. Dampen slump cone and the bottom of the soil pan.
2. Hold cone in place by standing on the two foot pegs.
3. Fill cone 1/3 of its volume (≈3 scoops).
4. Rod each layer with 25 strokes of the tamping rod, making sure that each layer is rodded evenly. Rod the bottom layer throughout its depth. Rod the second layer and the top layer each throughout their depths, so that the strokes just penetrate into the underlying layer.
5. In filling and rodding the top layer, heap the S/B above the mold before rodding is started. If the rodding operation results in subsidence of the S/B below the top edge of the mold, add additional S/B to keep an excess of S/B above the top of the mold at all times. After the top layer has been rodded, strike off the surface of the S/B with the tamping rod.
6. Remove the mold immediately from the concrete by raising it carefully in a vertical direction. Raise the mold a distance of 12 inches in 5±2 seconds by a steady upward lift with no lateral or torsional motion. Complete test without interruption.
7. Immediately measure the slump by determining the vertical difference between the top of the mold and the displaced original center of the top surface of the specimen.
8. Record slump in terms of inches.

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Revision 1-032585
Sheet 1 of 1

pH MEASUREMENT

(Using Auto Control)

EQUIPMENT:

Corning pH meter 140
pH probe
test liquid
100 ml beaker

MEASUREMENT PROCEDURE:

1. Rinse electrodes with test liquid or deionized water.
2. Immerse electrodes in test liquid in a 100 ml beaker and press "AUTO" and "=".
3. Record the pH reading after stable endpoint is reached. (The "pH" and "A" LEDs will flash until a stable endpoint is reached, then the display will freeze and the LEDs will stop flashing and stay on.)
4. Recant the slurry for future use.

CALIBRATION (1-POINT):

1. Press mode to select pH mode ("pH" LED will flash).
2. Rinse electrodes with pH 7.00 buffer or deionized water.
3. Immerse electrodes in pH 7.00 buffer; press "CAL" until the 7 LED flashes and then press "AUTO". The auto "A" and 7 LEDs will flash until a stable endpoint is reached, then they will stop flashing and stay on. The display will read 7.00.)

CALIBRATION (2-POINT):

1. Perform steps 1 thru 3 in 1-point calibration procedure.
2. Select second buffer, pH 4.00 or pH 10.01.
3. Rinse electrodes with appropriate second buffer or deionized water.
4. Immerse electrodes in the second buffer and press "CAL". The "A" and 4/10 LEDs will flash. When a stable endpoint is reached, the LEDs will stop flashing and stay on. Display will read 4.00 or 10.01, depending on the second buffer used.

SLP No. E-02
Revision 1-032585
Sheet 1 of 2

SLURRY CONDUCTANCE

EQUIPMENT:

conductivity meter
conductivity cell
250 ml beaker
temperature probe
250 ml test slurry

PROCEDURE:

1. Pour test slurry into beaker to 250 ml mark.

2. Set conductivity meter function switch to temperature compensated conductance position.

3. Immerse conductivity cell into test slurry. The electrodes must be submerged and the electrode chamber free of trapped air. Tap cell to remove any bubble and dip it into the slurry several times to assure complete wetting.

4. Connect conductivity cell leads to meter terminals.

5. Rotate temperature compensation control to desired percentage/°C setting, plug in temperature probe, and place into test slurry.

6. Rotate range switch to lowest range position which gives a within-range meter reading. (An over-range value is indicated by a "1" followed by blanks. An under-range is indicated by a small letter "u". Readings may be in error when operating in the under-range condition. On the 0.1-2 micromho range, allow extra time to stabilize.)

7. Record stabilized conductance value (c).

8. Set the function switch to temperature position, read and record displayed temperature in °C.

9. Record conductance as micromho per % bentonite concentration.

$$\text{CONDUCTIVITY} = C \times K$$

$$\text{RESISTIVITY} = \frac{1}{C} \div K = \frac{1}{C \times K}$$

$$K = \text{cell constant} = 1.0/\text{cm or } 100/\text{m}$$

NOTES:

1. After use, clean conductivity cell with foaming acid tile cleaner or with a 1:1 solution of isopropyl alcohol 10 N HCl. Rinse cell with distilled water, allow to air dry and store in deionized water.

2. When testing water or chemical-based bentonite slurries, temperature compensated conductance reference values should first be obtained on the corresponding water or chemical solution having no bentonite. Bentonite slurry specific conductance is recorded as the difference in conductance between the slurry and the reference standard.

SPECIFIC CONDUCTANCE

EQUIPMENT:

- conductivity meter
- conductivity cell
- 250 ml beaker
- temperature probe
- 250 ml test sample

PROCEDURE:

1. Pour test sample into beaker to 250 ml mark.

2. Set conductivity meter function switch to temperature compensated conductance position.

3. Rinse conductivity cell with test sample. Immerse conductivity cell into test sample. The electrodes must be submerged and the electrode chamber free of trapped air. Make sure the slot in the top of the probe is submerged and sealed with sample. Tap cell to remove any bubble and dip it into the sample several times to assure complete wetting. Probe must be held upright to obtain accurate reading.

4. Make sure conductivity cell leads are connected to meter terminals.

5. Rotate temperature compensation control to desired percentage/°C setting (this will be 1.95 unless stated stated otherwise) and record on data sheet. Plug in temperature probe and place into test sample.

6. Rotate range switch to lowest range position which gives a within-range meter reading. (An over-range value is indicated by a "1" followed by blanks. An under-range is indicated by a small letter "u". Readings may be in error when operating in the under-range condition. On the 0.1 - 2 micromho range, allow extra time to stabilize.)

7. Record stabilized conductance value (c) on specific conductance data sheet.

8. Set the function switch to temperature position, read and record displayed temperature in °C.

9. Set the function switch to read and record stabilized uncompensated conductance value.

10. Record the range switch setting by entering the number corresponding to the appropriate range:

Range Number	Setting
1	2 µ℧
2	20 µ℧
3	200 µ℧
4	2 m℧
5	20 m℧
6	200 m℧

11. Record conductance as micromho/cm.

$$\text{CONDUCTIVITY} = C \times K$$

$$\text{RESISTIVITY} = \frac{1}{C} \div K = \frac{1}{C \times K}$$

$$K = \text{cell constant} = 1.0/\text{cm or } 100/\text{m}$$

NOTES:

1. After use, clean conductivity cell with foaming acid tile cleaner or with a 1:1 solution of isopropyl alcohol 10 N HCl. Rinse cell with distilled water, allow to air dry and store in deionized water.

2. When testing water or chemical-based bentonite slurries, temperature compensated conductance reference values should first be obtained on the corresponding water or chemical solution having no bentonite. Bentonite slurry specific conductance is recorded as the difference in conductance between the slurry and the reference standard.

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SPECIFIC CONDUCTANCE DATA SHEET

PROJECT:____

DATE:____________________ TECHNICIAN:____________________

SAMPLE ID	READING WITH COMP	READING W/O COMP	TEMP °C	RANGE NO. 1) 2 μ℧ 4) 2 m℧ 2) 20 μ℧ 5) 20 m℧ 3) 200 μ℧ 6) 200 m℧	TEMP COEF	CONDUCTANCE μ℧

Cell Constant = 1.0/cm

If range 4, 5, or 6 is used, multiply reading with comp by 1000 to obtain conductance in μ℧ /cm

Conductance (μ℧ /cm) = Reading with comp (μ℧) x Cell constant (cm)

Conductance (μ℧ /cm) = Reading with comp (m℧) x Cell constant (cm) x 1000 μ℧/m

SLURRY DENSITY

(Mud Weight)

EQUIPMENT:

standard API mud balance
thermometer (accurate to 0.5°C)

PROCEDURE:

A. Prepare bentonite slurry per SLP No. S-01 or S-02 per applicable experimental design.

B. Allow slurry to hydrate undisturbed for 24 hours (or other, per applicable experimental design) in moisture room.

C. (OPTIONAL) Re-mix slurry per SLP No. S-03.

1. Set instrument base on flat, level surface.
2. Measure and record slurry temperature in °C.
3. Fill clean, dry cup with slurry to be tested. Insert cup lid and rotate until firmly seated, expelling excess slurry and trapped air through orifice in lid.
4. Carefully wash or wipe the outside of the cup clean and dry.
5. Place balance arm on base with knife edge on fulcrum.
6. Move rider until graduated balance arm is level, as indicated by the level vial on the beam.
7. Read density in lb/ft^3 along the inside edge of the rider (closest to mud cup).
8. Report slurry density in pounds per cubic foot (lb/ft^3).
9. Replicate test as required by experimental design.
10. Return slurry to storage for future test (24-hour, 7-day) if called for by experimental design. Otherwise, discard slurry per applicable safety procedures.

CALIBRATION:

a. Calibration is carried out using the above procedure, substituting water for slurry. The level bubble should be centered when the rider is set at the water calibrator mark on graduated beam.

b. If the beam is not balanced, adjust by adding or removing sand from the well at the end of the beam.

REFERENCE: API RP 13B, Tenth Edition, Sec. 1.1-5.

MARSH FUNNEL VISCOSITY

EQUIPMENT:

standard API Marsh funnel viscometer
graduated measuring cup (1 quart)
stopwatch (accurate to 0.1 sec)
thermometer (accurate to 0.5°C)

PROCEDURE:

1. Prepare bentonite slurry per SLP No. S-01 or S-02 per applicable experimental design.

2. Allow slurry to hydrate undisturbed for 24 hours (or other, per applicable experimental design) in moisture room.

3. Hold clean, dry funnel upright with finger covering the orifice. Pour slurry into funnel until slurry level reaches the bottom of the screen.

4. Remove finger from orifice and simultaneously start stopwatch. Measure time required for slurry to reach the 1-quart level in the cup. Record time to nearest 0.1 second.

5. Measure and record slurry temperature in °C.

6. Report viscosity in Marsh seconds at measured temperature.

7. Replicate test as required by experimental design.

8. Return slurry to storage for future test (24-hour, 7-day) if called for by experimental design. Otherwise, discard slurry per applicable safety procedures.

REFERENCE: API RP 13 B, Tenth Edition, Sec. 2.1-2.

ROTATIONAL VISCOMETER

EQUIPMENT:

N.L. Baroid rheometer model 286
rotational viscometer
stopwatch (accurate to 0.1 sec)
thermometer (accurate to 0.5°C)

PROCEDURE:

1. Prepare bentonite slurry per SLP No. S-01 or S-02 per applicable experimental design.
2. Assemble rheometer by installing shield, bob and rotor.
3. Record slurry temperature, °C.
4. Pour slurry into the cup up to the scribed line on the inside surface. Position cup on the viscometer using pins on cup bottom and holes in rheometer base plate. Immerse sleeve into slurry to the scribed line.
5. Record zero (at rest) indicator dial reading, if any.
6. Stir slurry at 600 rpm and record stabilized indicator dial value.
7. Shift rheometer to 300 rpm and record stabilized indicator dial value.
8. Stir slurry for 10 seconds at high speed (in excess of 600 rpm).
9. Turn rpm selector knob to "off". Allow slurry to stand undisturbed for 10 seconds after the rotor has stopped.
10. Switch rpm selector knob to GEL position (3 rpm). Observe the maximum (peak) indicator dial value after starting rotation. Record peak value as 10-second gel strength in lb/100 ft^2.
11. Repeat steps 7, 8, and 9, allowing slurry to sit undisturbed for 10 minutes (step 8). Record peak value as 10-minute gel strength in lb/100 ft^2.
12. Return slurry to storage for future test (24-hour, 7-day) if called for by experimental design. Otherwise, discard slurry per applicable safety procedures.

CALCULATIONS:

Apparent Viscosity (cP) = $\frac{\text{600 rpm reading}}{2}$

Plastic Viscosity (cP) = (600 rpm reading) - (300 rpm reading)

Yield Point (lb/100ft^2) = (300 rpm reading) - plastic viscosity

CALIBRATION:

Per prescribed QA/QC frequency, determine 300 rpm and 600 rpm reading for deionized water at 21°C. Compute % difference for each relative to calibration standard of ____ (300) and ____ (600). Record in calibration log book. If result exceeds ____, notify principal investigator.

REFERENCE: API RP 13B, Tenth Edition, Sec. 2.4-6

API FILTRATE LOSS

EQUIPMENT:

standard API filter press
25 ml graduated cylinders
dial calipers
250 ml beaker
stopwatch (accurate to 0.1 sec)
filter paper, Dresser - Magcobar 2-189 or equivalent
spatula

PROCEDURE:

A. Prepare bentonite slurry per SLP No. S-01 or S-02 per applicable experimental design.

B. Allow slurry to hydrate undisturbed for 24 hours (or other, per applicable experimental design) in moisture room.

C. (OPTIONAL) Re-mix slurry per SLP No. S-03 if necessary to achieve uniform mix.

1. Assemble filter press cell in the following order: base cap, rubber gasket, screen, filter paper, rubber gasket and filtrate cylinder.

2. Fill the cylinder with slurry to within 1/4" of the top and place in filter press frame.

3. Position top cap (connected to the pressure source) on the filter press cell, making sure the rubber gasket is in place. Secure cell with T-screw.

4. Place a clean, dry 25 ml graduated cylinder under the filtrate drain on the support stand.

5. Open the cell pressure valve, close the cell bleed valve and the in-line valve, and adjust the regulator to 100 psi.

6. Open the in-line valve and start stopwatch.

7. Record the volume of filtrate collected (ml) at 7.5 minutes total elapsed time. (This amount doubled should constitute an estimate of the total 30-minute filtrate volume.)

8. Record the volume of filtrate collected (ml) at 30.0 minutes total elapsed time.

9. Shut off pressure at the regulator, open bleed valve to remove system pressure, and close the filter press cell valve.

10. Loosen the T-screw, remove the cell top cap, remove cell from the frame and decant slurry into beaker.

11. Disassemble filter cell and carefully remove filter paper on which the filter cake has been formed.

12. Carefully remove excess slurry from filter cake using edge of spatula.

13. Measure and record thickness (mm) at four points on the filter cake using dial calipers.

14. Average four measurements, subtract thickness of filter paper, and record.

15. Determine moisture content of filter cake per SLP No. G-01.

16. Discard filtrate and unfiltered slurry per applicable safety procedure.

REFERENCE: API RP 13B, Tenth Edition, Sec. 3.1-3.

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ACETONE/BENTONITE DISPOSAL PROCEDURE

WA #08 Only

PROCEDURE

All of the acetone/bentonite slurries produced as a result of work on Work Assignment #08 will ultimately be disposed of by incineration. This requires temporary storage of the waste in suitable small containers until sufficient volume has been generated to warrant notification of the EPA hazardous waste disposal contractors. The small containers filled with waste will be stored in the satellite accumulation area. Be sure to log in the waste on the clipboard when putting the waste into the waste storage locker. (See Satellite Accumulation Area sheet.) The waste contractor will pack 5 to 8 gallons of the liquid waste into a 30-gallon fiber drum which will then be overpacked in a 55-gallon drum. The drum(s) will be transported to GSX Disposal Facility where the waste will be incinerated.

1. All waste handling will be performed in the Hazardous Waste Lab, Room 130, or the Permeability Lab, Room 132. NO EXCEPTIONS!!!
2. At no time will acetone or acetone container rinsings be disposed of down the sink.
3. Waste acetone or acetone slurries will be temporarily stored in the original acetone containers or in the glass waste disposal bottles stored on the supply shelves. These waste containers will be clearly labeled with percent acetone, percent water, percent bentonite, total volume, date, initials of researcher, and work assignment number.
4. If additional waste is added to a partially full container, a second label will be added to the container with all of the pertinent information for the additional waste. Both labels should be easily read. Never put the second label on top of the original label.
5. Any given waste container may combine different concentrations of acetone solutions, but only ONE chemical will ever be stored in any one container.

SAFETY CONSIDERATIONS

For your protection wear:

- Goggles (not safety glasses)
- Lab coat
- Butyl rubber gloves (heavy black gloves)

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METHANOL/BENTONITE DISPOSAL PROCEDURE

WA #08 Only

PROCEDURE

All of the methanol/bentonite slurries produced as a result of work on Work Assignment #08 will ultimately be disposed of by incineration. This requires temporary storage of the waste in suitable small containers until sufficient volume has been generated to warrant notification of the EPA hazardous waste disposal contractors. The small containers filled with waste will be stored in the satellite accumulation area. Be sure to log in the waste on the clipboard when putting the waste into the waste storage locker. (See Satellite Accumulation Area sheet.) The waste contractor will pack 5 to 8 gallons of the liquid waste into a 30-gallon fiber drum which will then be overpacked in a 55-gallon drum. The drum(s) will be transported to GSX Disposal Facility where the waste will be incinerated.

1. All waste handling will be performed in the Hazardous Waste Lab, Room 130, or the Permeability Lab, Room 132. NO EXCEPTIONS!!!

2. At no time will methanol or methanol container rinsings be disposed of down the sink.

3. Waste methanol or methanol slurries will be temporarily stored in the original methanol containers or in the glass waste disposal bottles stored on the supply shelves. These waste containers will be clearly labeled with percent methanol, percent water, percent bentonite, total volume, date, initials of researcher, and work assignment number.

4. If additional waste is added to a partially full container, a second label will be added to the container with all of the pertinent information for the additional waste. Both labels should be easily read. Never put the second label on top of the original label.

5. Any given waste container may combine different concentrations of methanol solutions, but only ONE chemical will ever be stored in any one container.

SAFETY CONSIDERATIONS

For your protection wear:

- Goggles (not safety glasses)
- Lab coat
- Butyl rubber gloves (heavy black gloves)

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XYLENE/BENTONITE DISPOSAL PROCEDURE

PROCEDURE

All of the xylene/bentonite slurries produced as a result of work on Work Assignment #08 will ultimately be disposed of by incineration. This requires temporary storage of the waste in suitable small containers until sufficient volume has been generated to warrant notification of the EPA hazardous waste disposal contractors. The small containers filled with waste will be stored in the satellite accumulation area. Be sure to log in the waste on the clipboard when putting the waste into the waste storage locker. (See Satellite Accumulation Area sheet.) The waste contractor will pack 5 to 8 gallons of the liquid waste into a 30-gallon fiber drum which will then be overpacked in a 55-gallon drum. The drum(s) will be transported to GSX Disposal Facility where the waste will be incinerated.

1. All waste handling will be performed in the Hazardous Waste Lab, Room 130, or the Permeability Lab, Room 132. NO EXCEPTIONS!!!

2. At no time will xylene or xylene container rinsings be disposed of down the sink.

3. Waste xylene or xylene slurries will be temporarily stored in the original xylene containers or in the glass waste disposal bottles stored on the supply shelves. These waste containers will be clearly labeled with percent xylene, percent water, percent bentonite, total volume, date, initials of researcher, and work assignment number.

4. If additional waste is added to a partially full container, a second label will be added to the container with all of the pertinent information for the additional waste. Both labels should be easily read. Never put the second label on top of the original label.

5. Any given waste container may combine different concentrations of xylene solutions, but only ONE chemical will ever be stored in any one container.

SAFETY CONSIDERATIONS

For your protection, wear:

- goggles (not safety glasses)
- lab coat
- PVA gloves (heavy red gloves) Use only with 100% xylene. Do not use PVA gloves with water; PVA is water soluble.
- Nitrile gloves (green gloves) Use with xylene/water solutions.